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A SURVEY OF INTERNAL AND EXTERNAL NOISE ENVIRONMENTS IN US ARMY AIRCRAFT

DONALD C. GASAWAY, CAPT, MSC, USAF

JIMMY L. HATFIELD, CAPT, MSC, USA

UNITED STATES ARMY MEDICAL RESEARCH

AND DEVELOPMENT COMMAND

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ABSTRACT

This report presents and describes representative internal and external noise environments for each major type of Army aircraft during normal operations. Measurements for all fixed- and rotary-wing aircraft are classified, when appropriate, into four major categories: ground operations, hovering flight, normal, and maximum cruise conditions. The contributions of major noise generators in each type of aircraft is discussed in detail.

APPROVED: Harold R Chappell
HAROLD R. CHAPPELL
Major, MC
Commanding

FOREWORD

This report summarizes the results of a research program designed to survey the internal and external noise environments associated with the operation of Army aircraft. The acoustical measurements were conducted by the authors at Fort Rucker, Alabama.

A program of this nature cannot be accomplished without the cooperation of many individuals and organizations. Special credit is due the Flight Operations Division, U. S. Army Aviation Test Board, and the AC of S, G-3, USAAVNC, Fort Rucker, Alabama, for providing aircraft and crew members during field measurements.

The figures were prepared by Airman Second Class James D. Harkness, Audiology Department, School of Aerospace Medicine, Brooks AFB, Texas. Miss Marilyn Helms typed the final manuscript and provided editorial assistance during the preparation of the final report.

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INTRODUCTION

Modern Army aircraft are increasing in complexity and as their performance characteristics make greater demands on the physical, mental, and psychological capabilities of crew members, designers are recognizing and attempting to design aircraft and systems that remain within the optimum range of human capabilities and limitations. Sophisticated aircraft and systems require an increased appreciation of man's ability, efficiency and performance.

Medical personnel are well aware that an unwarranted reduction in the total effectiveness of an aircraft may result when considerations for the aviator's comfort and safety are overlooked or ignored. The greater and more extensive the awareness of medical personnel of the undesirable aspects of noise energies generated by aircraft, the greater will be the emphasis placed on minimizing undesirable noise exposures in Army aircraft of the future.

Throughout the reading of this paper, it should be remembered that the noise environments described and illustrated herein are representative of only one particular set of conditions and the noise may vary from one situation to another. To best evaluate a given noise environment, one must complete a detailed noise evaluation of the particular noise exposure under question. Although it is not the intent of this report to present noise exposures that should be accepted unquestionably as representing a set noise exposure for a given type of aircraft, the noise measurements given do offer a means of making a fairly accurate estimate of the type and degree of noise exposures produced by similar noise generators operating at similar power and flight conditions.

Aeromedical personnel can obtain detailed information concerning the systems and components within aircraft by referring to appropriate Flight and Ground Maintenance Manuals. Changes and modifications of an aircraft's power plants, auxiliary power and related systems, structural modifications, communications and other electronic systems may cause radically different noise exposures. By referring to the information and data contained in these basic manuals, medical personnel can obtain a more comprehensive understanding of the different noise generators as well as mission profiles flown by a given aircraft. This knowledge, coupled with data and information on the noise exposures generated during different phases of operation, provides a meaningful and comprehensive understanding of the relative significance of the noises associated with the aircraft's operation.

METHODS AND MATERIALS

The methodology used to accomplish the noise evaluations reported within this study was carefully established to provide information and data that would be of maximum benefit to aeromedical personnel. The data was measured and recorded in decibels (db), reference 0.0002 microbar (dyne/cm^2), so that the levels reported would have the greatest degree of relevancy to predictable human psychophysical response. In each instance, the noise environments are reported by octave bands, ranging from 37.5 through 9600 cps. Standard "C" scale measurements are reported as over-all levels (OAL).

Instrumentation and Calibration.

The noise levels reported in this study were measured with a Rudmose Noise Analyzer, Model RA-100 (Serial No. 149). The Model RA-100 is a portable unit designed for analyzing noise in terms of sound pressure levels within octave bands. The A, B, and C scales of the instrument correspond to the networks for basic sound level meters, and the eight octave bands are true band-pass filters extending from 37.5 through 9600 cps. The microphone used with the Model RA-100 was the standard dynamic type microphone supplied with the analyzer (Rudmose Associates Microphone, Serial No. 50).

Prior to each use the analyzer was properly calibrated according to recommendations set forth in the Instruction Manual for the Model RA-100 Sound Analyzer. Routine calibration checks (primarily electrical) were accomplished in the field. A 25-foot microphone extension cable, supplied with the Model RA-100 analyzer, was used on several occasions. No loss or change in calibration occurred due to the use of the microphone extension cable.

Positions and Locations.

The majority of measurements, unless specified otherwise, were taken with the microphone located at head level positions.

Internal measurements: Most internal measurements were recorded with the microphone located at head level of an occupant while in a standing or sitting position, as the case may be. Standing positions were usually limited to center line (aisle) measurements which were usually completed in multiplace aircraft and sitting

positions were usually recorded with the microphone placed at head level (approximately 36 to 48 inches above the floor) of persons sitting in forward-facing chairs or side-placed troop seats.

External measurements: Most external measurements were taken with the microphone of the noise analyzer placed approximately 50 inches above the surface of the ground. All of the external noise measurements were recorded while the aircraft was operating in an open sod surfaced field. No topographical obstructions, shrubbery, or other conditions existed which might have contributed to undesirable noise propagation phenomenon. All external measurements were completed during conditions in which the variable surface winds did not exceed six to eight knots. The ambient temperature during these measurements ranged from 45 to 75 degrees Fahrenheit. In fact, ideal weather conditions prevailed during the time in which all of these measurements were made.

The angles from the aircraft at which noise measurements were taken are referred to in degrees. In all instances, 0 degrees refers to a location directly in front (nose) of the aircraft and 180 degrees refers to a location directly behind (tail) the aircraft. Lateral measurements are designated as right or left; for example, 90 degrees on the right or 90 degrees on the left side of the aircraft. If full circle measurements (0 to 360 degrees) are employed, the actual location of a measurement is referred to as an angle from 0 to 180 degrees to indicate the right side; angles from 180 to 360 degrees to indicate the left side.

SURVEY OF NOISE PRODUCED BY VARIOUS U. S. ARMY AIRCRAFT

The present Army aviation inventory includes approximately 7,000 aircraft. Contained within this inventory is a large variety of fixed- and rotary-wing aircraft. The following illustrations and descriptions are intended to present a summary of both internal and near-field noise exposures generated by major U. S. Army aircraft. For simplicity, the aircraft on which noise measurements were completed are listed under four major classifications as designated by AR 700-26:

1. Rotary-Wing Aircraft.

   UH-1A
   UH-1B
   UH-1D
   OH-13H
   UH-19D
   CH-21C
   OH-23D
   CH-34C
   CH-37B
   CH-47A

2. Fixed-Wing Aircraft.

   a. Utility Aircraft

      U-1A
      U-6A
      U-8D
      U-8F
      U-9B

   b. Short Take-Off and Landing Aircraft (STOL)

      OV-1A
      OV-1B
      CV-2B

c. Observation Aircraft

O-1E

The noise exposures, as specified, will afford the reader with a basic understanding of the noise characteristics of a given aircraft during various modes of airborne and ground operations. Detailed information concerning characteristics of noise generators, i.e., reciprocating versus gas-turbine engines; propeller, main rotor, and antitorque systems; transmission, gear-reduction and gear-distribution systems, etc. is contained in USAARU Report 63-1, June 1963.

Additional acoustical measurements on several Army aircraft may be found in TREC Technical Report 61-72, June 1961.

1. ROTARY-WING AIRCRAFT.

UH-1A, B, D.

For simplicity, the three examples of the Bell "Iroquois," the UH-1A, UH-1B, and the UH-1D are discussed together since all three models possess essentially the same basic aircraft components and, therefore, have similar noise characteristics.

Aircraft Description: UH-1A aircraft are fitted with a Lycoming T53-L-1A turboshaft engine (no longer in production) and the UH-1B and UH-1D are fitted with a later model of the same engine, the Lycoming T53-L-9. The T53-L-1A engine delivers approximately 860 shaft horsepower at 6,680 rpm when operating at maximum power. Approximately 102 pounds of jet thrust are obtained from the exhaust of the engine. The T53-L-9 engine delivers about 1,100 shaft horsepower at 6,610 rpm during operation at maximum power, and an additional 115 to 125 pounds of jet thrust are obtained from the exhaust of the engine.

All three aircraft are fitted with a two-blade main and tail rotor system. The diameter of the UH-1A main rotor is 43'9" and for the UH-1B and UH-1D the diameter is 44'0". In addition, the UH-1B and UH-1D rotor blades have a larger chordwise width. The antitorque rotor of the UH-1A is 8'5" whereas the antitorque rotor of the UH-1B and the UH-1D is 8'6". All three aircraft have an engine-to-main rotor gear reduction of 20.4-to-1.

Internal Noise: The noise within the helicopters during various phases of ground and flight operation is dependent on several factors. Plottings in Figure 1, page 9, show results of noise measurements taken at various internal locations within the UH-1A during ground level operation. These measurements were completed while the engine was operating at 6,600 rpm (compressor stages) and the rotor was rotating at 325 rpm. The engine was producing approximately 8 psi of torque and the rotor blades were not receiving lift torque. Noise exposures generated within the helicopter are equally distributed at head level throughout various internal occupied locations. The most intense single noise generating mechanism is the main rotor. At 325 rpm the main rotors have a blade passage frequency of 10.8 times per second and a blade tip velocity of 745.5 feet per second (0.667 Mach). Figure 2, page 10, shows noise measurements made at similar locations during flight at normal cruise (60 knots IAS). During these measurements the aircraft was flying at about 500 feet altitude and the engines were operating at 6,500 rpm, 20 psi torque, and the rotors were rotating at 325 rpm. Once again, the noise levels generated within the helicopter are almost identical at three different internal locations from the front to the rear of the aircraft.

Noise plottings in Figure 3, page 11, indicate that the differences in noise exposures within the helicopter, when measured at the same location but during different power operations, are the direct result of flight profile. In general, the internal noise levels within the UH-1A helicopter were found to be very similar from one internal location to another during the same flight profile. The noise generated by the transmission sections of the engine become more noticeable in the rear of the helicopter than at forward positions. It is evident from the noise measurements depicted in Figure 4, page 12, that transmission noise is not highly evident at a location directly in front of the transmission housing, whereas noise plottings in Figure 5, page 13, show the presence of transmission type noise when measured at the side of the transmission housing. At the side of the unit the presence of the narrow-band type noise generated by the meshing and impacting of the gears within the gear-reduction and gear-distribution unit is quite noticeable. A transmission system mated to a gas-turbine power plant produces more intense high frequency noise than similar systems mated to reciprocating engines because the transmissions of gas-turbine engines require higher gear-reduction ratios and, therefore, higher speed gear meshing and impacting occurs.

Figure 6, page 14, shows results of noise measurements taken at the pilot's side (head level) in a UH-1B during three phases of operation. During ground operation the engine was operating at approximately 9 psi torque; during a hover torque was increased to 24 psi; and during cruise the torque was reduced to 21 psi. During cruise measurements the aircraft flew at an airspeed of 80 knots (IAS). Figure 7, page 15, shows noise measurements taken at head level in the right troop seat directly behind the pilot during three flight conditions: hover, normal, and maximum cruise. The airspeed during normal cruise was 80 knots (IAS) and during maximum cruise, 100 knots (IAS). The rotors contributed to the differences in noise levels and spectrum.

External Noise: The following noise plottings show results of noise measurements taken at 30 degree intervals on both right and left sides of the helicopter at a distance of 100 feet. During these measurements the aircraft was hovering, and the engines were operating at 6,300 rpm with the rotors rotating at 310 rpm. The main rotor had a blade passage frequency of approximately 10.3 times per second and a blade tip velocity of 710.9 feet per second (0.636 Mach). Figure 8, page 16, shows results of measurements taken directly in front and to the rear of the helicopter. At a location in front of the helicopter the most intense noise generator was the main rotor but at locations to the rear of the helicopter a complex combination of noises produced by the tail rotor, main rotor, and engine exhaust become evident. Figure 9, page 17, shows noise measurements taken at a location 30 degrees from the right and left side of the nose of the helicopter. These noise plottings demonstrate a more equally distributed noise field. Figure 10, page 18, shows measurements taken at 60 degrees from the front of the aircraft on the right and left side. Once again, the

noise measurements reveal that noise generated at these locations is relatively the same on both sides of the helicopter. The plottings in Figure 11, page 19, show results of measurements taken at a position directly to the right and left side of the helicopter (90 degrees). These noise plottings illustrate only slight differences. Figure 12, page 20, shows plottings of noise measurements completed at locations on the right and left sides of the aircraft (120 and 240 degrees). At locations on the left side,the noise spectrum is slightly higher due to the influence of noise emanating from the tail rotor. Although the over-all noise is basically the same, the influence of the tail rotor noise is most evident in the higher frequency range. Generally, the over-all noise generated on the left side of the helicopter will be slightly louder than the noise generated on the right side. This is due primarily to the influence of noise elements generated from the tail rotor. Also, the increased torque and blade pitch required to hover the helicopter results in a somewhat louder noise exposure at locations aft of the helicopter than at locations in front of the aircraft.

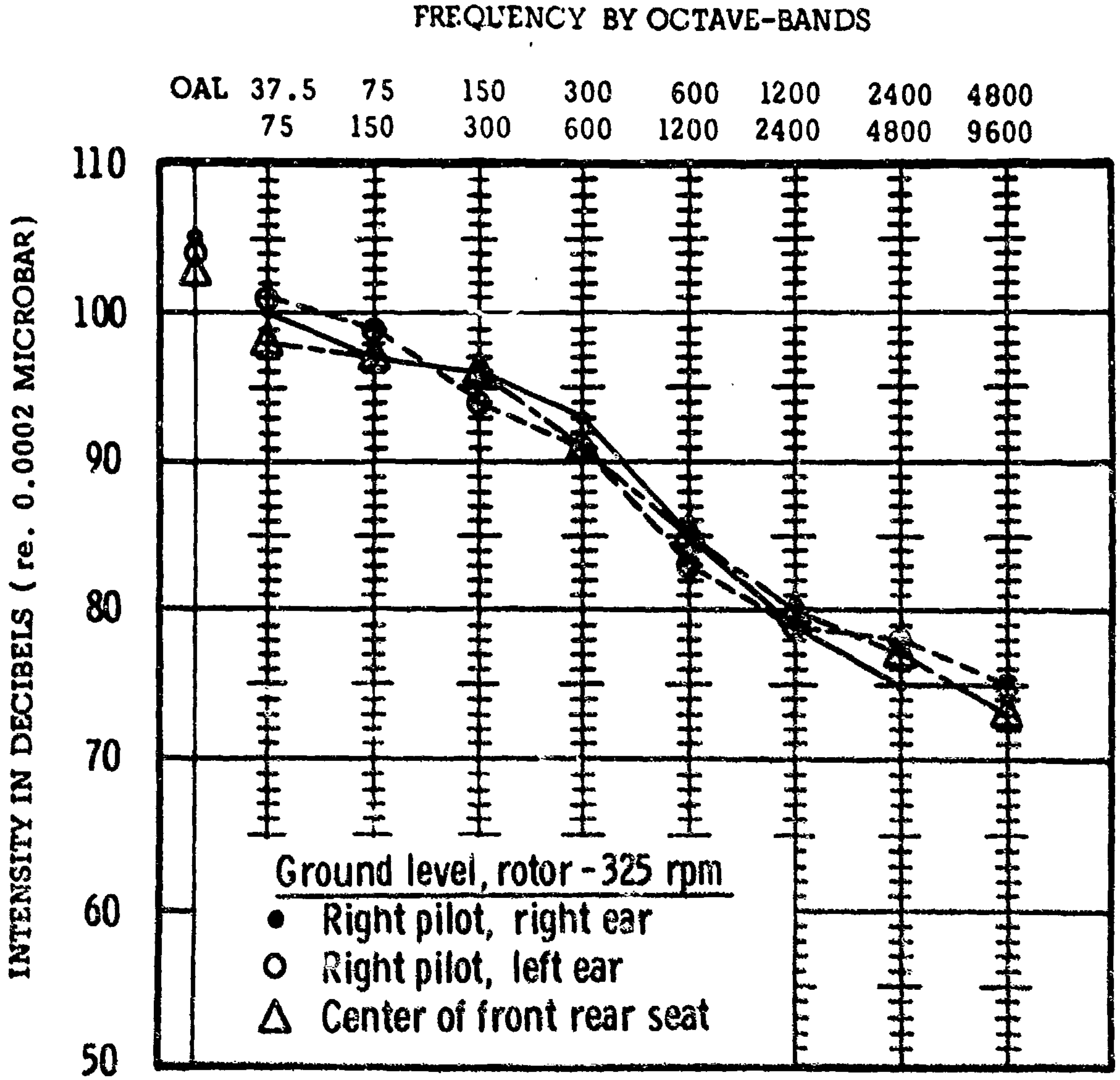

Fig. 1 Internal Noise of UH-1A Helicopter During Ground Operations, 6600 RPM, 8 PSI Torque

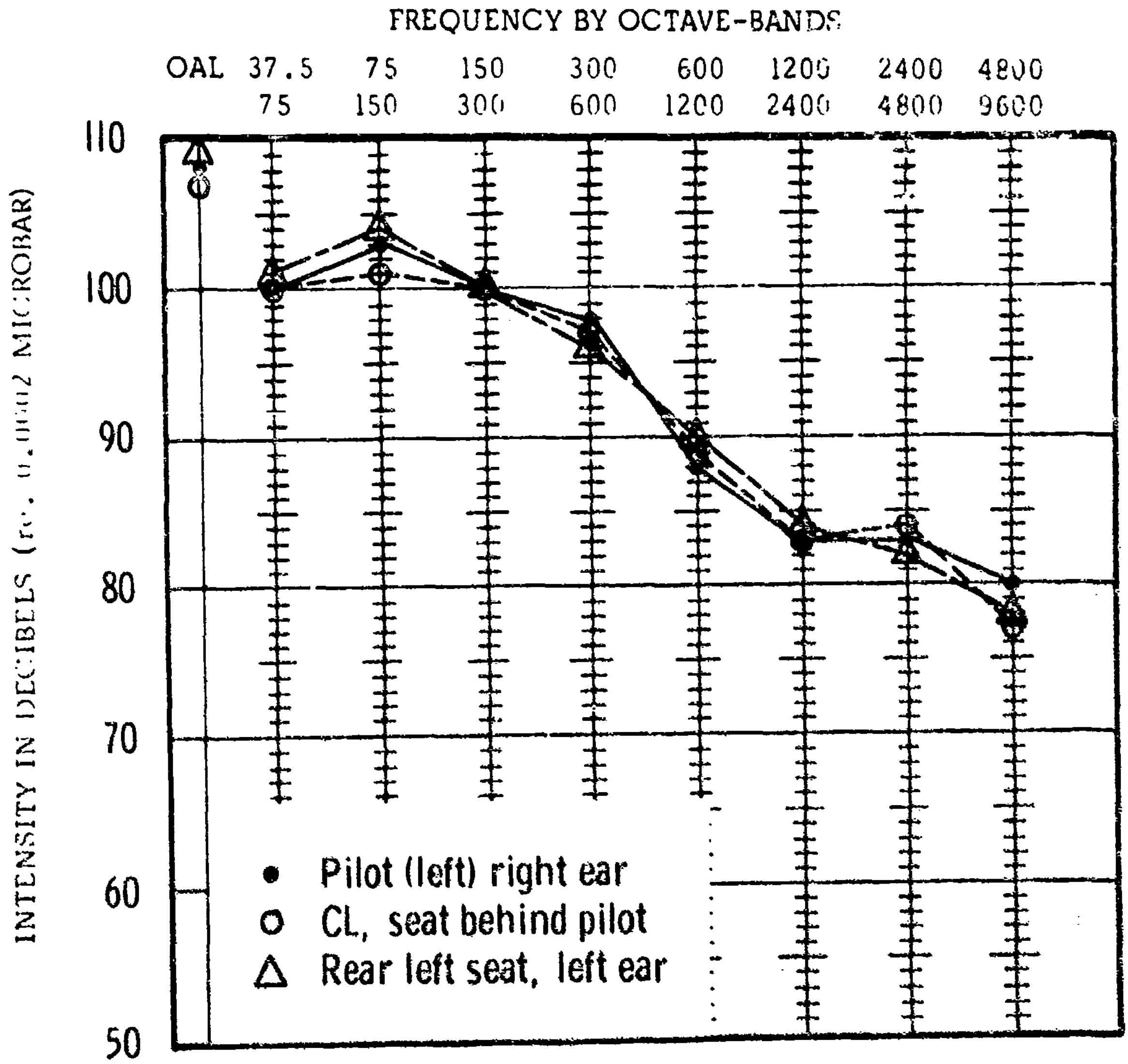

Fig. 2 Internal Noise of UH-1A Helicopter During Normal Cruise, 6500 RPM, 325 Rotor RPM, 20 PSI Torque, 60 Knots IAS

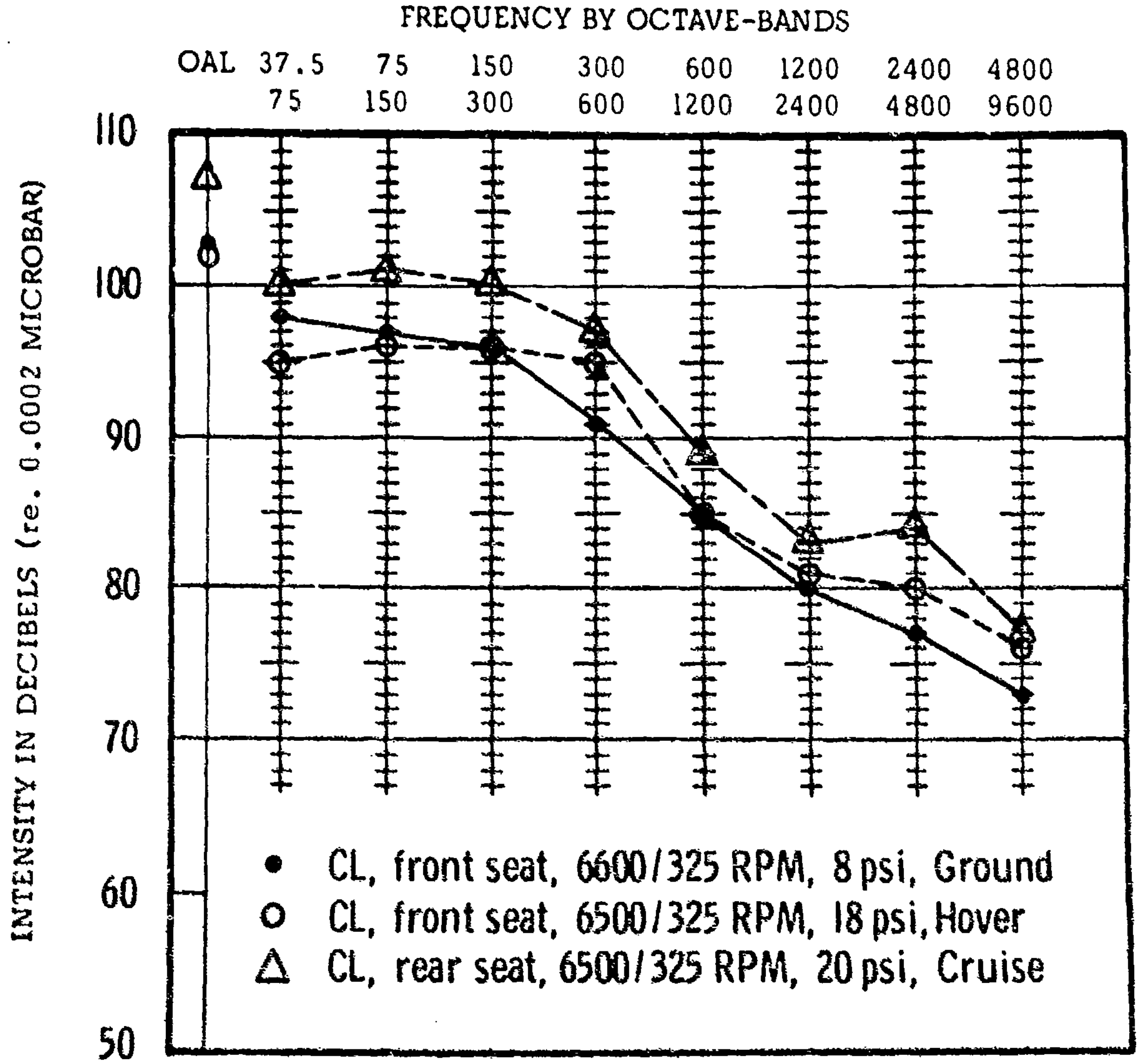

Fig. 3 Internal Noise of UH-1A Helicopter During Ground Operations, Hover, and Normal Cruise

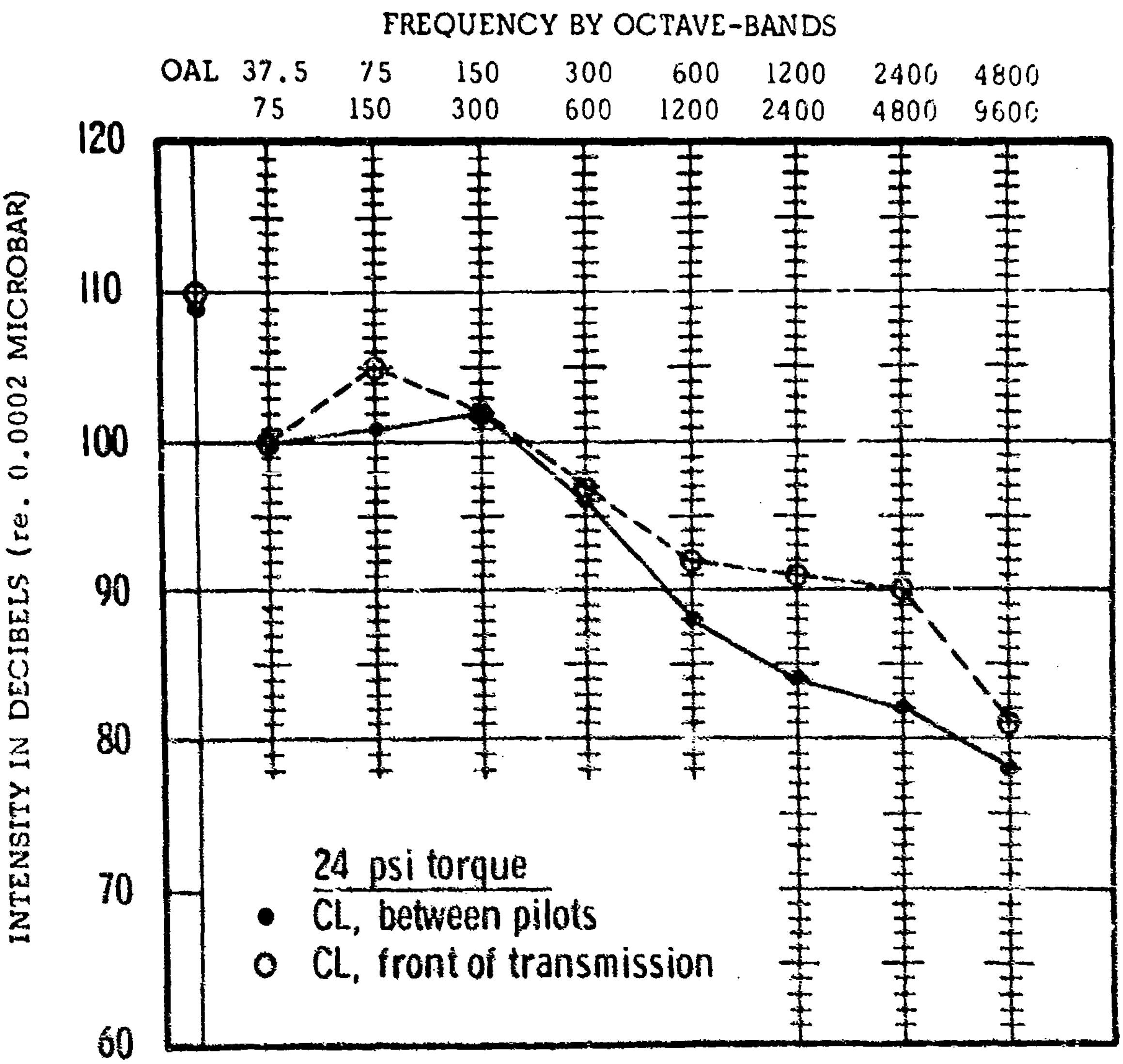

Fig. 4 Internal Noise of UH-1D Helicopter During Normal Cruise, 6600 RPM, 330 Rotor RPM, 80 Knots IAS

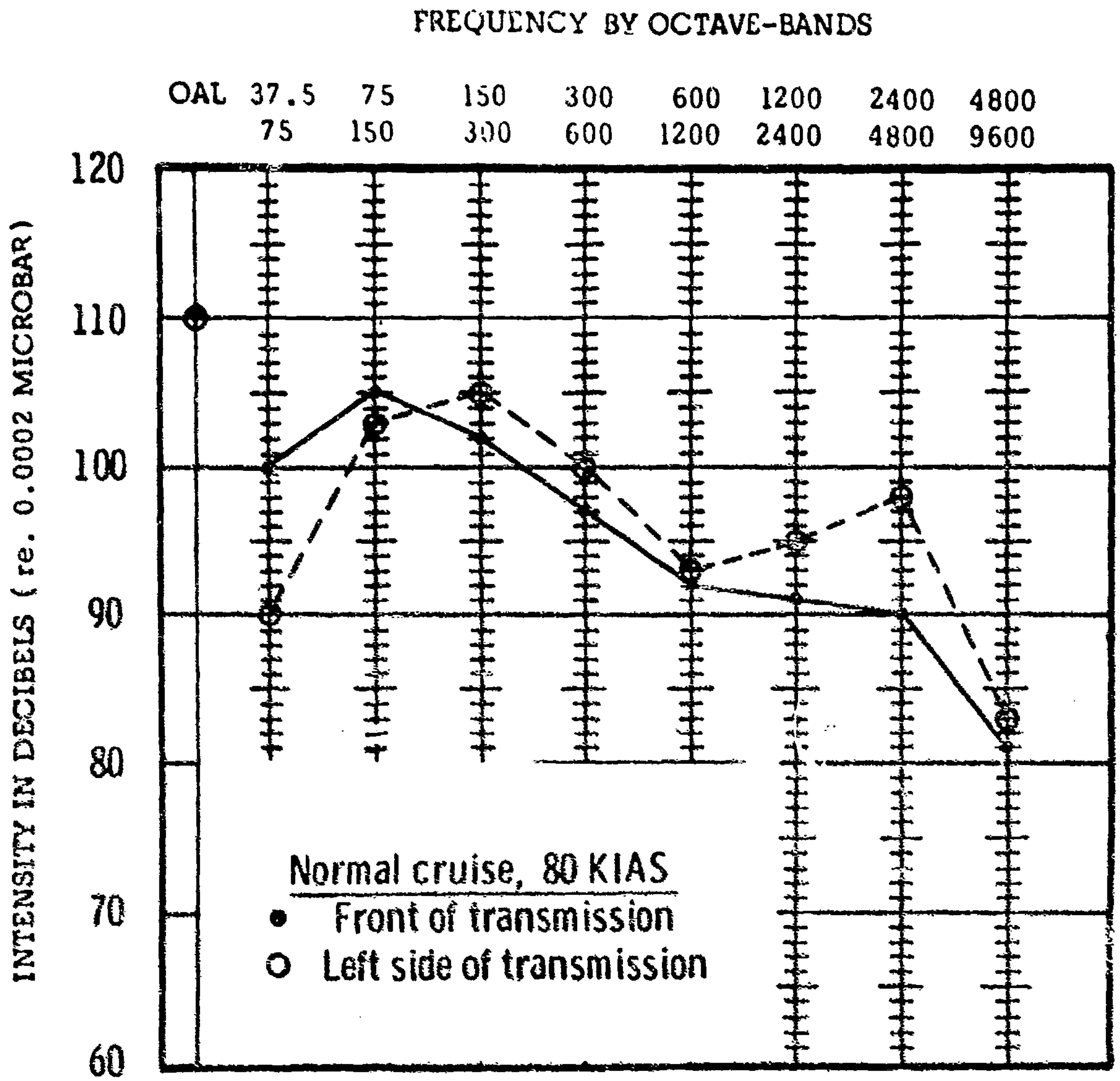

Fig. 5 Internal Noise of UH-1D Helicopter During Normal Cruise, 6600 RPM, 330 Rotor RPM, 24 PSI Torque

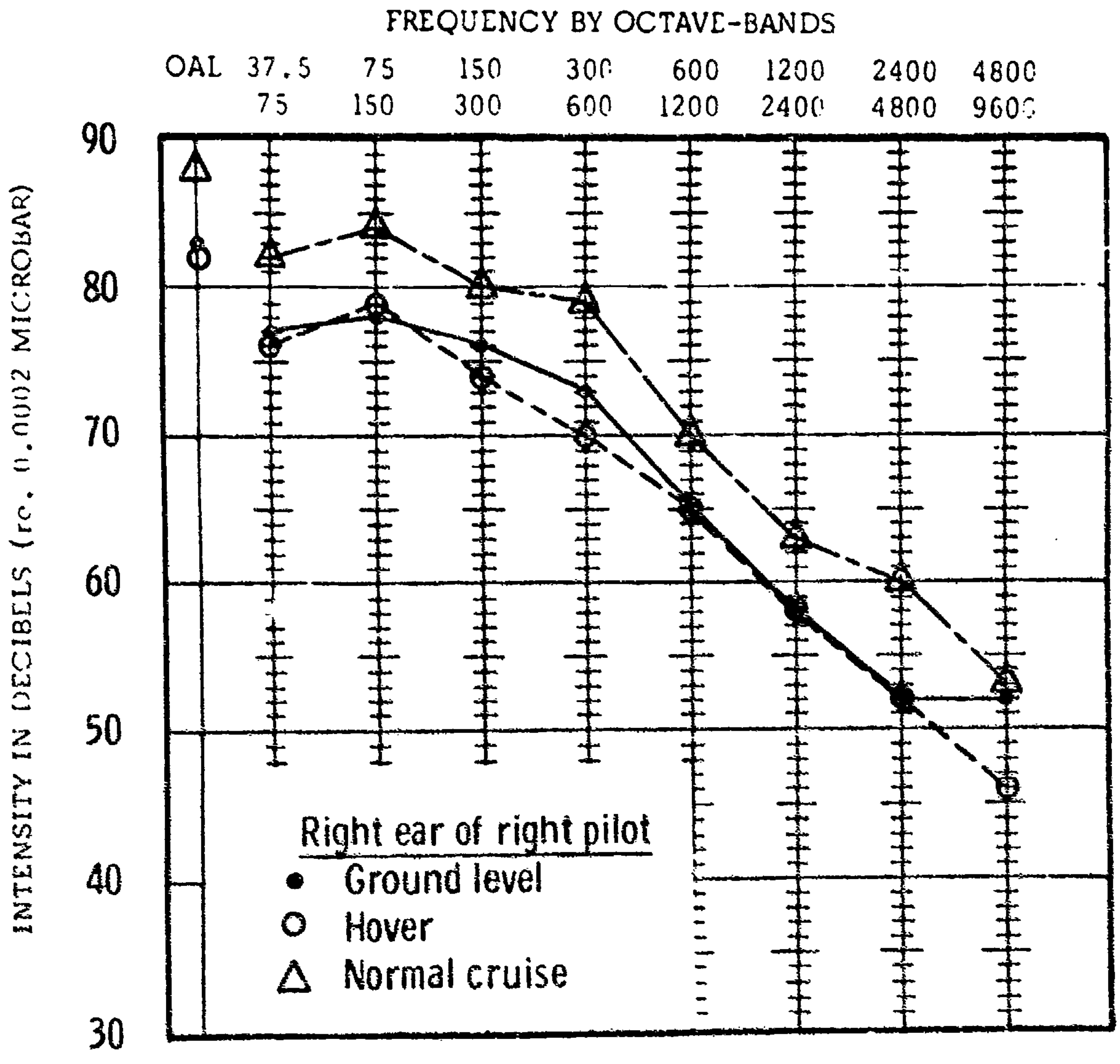

Fig. 6 Internal Noise of UH-1B Helicopter During Ground Operations at 9 PSI Torque; Hover at 24 PSI; and Normal Cruise at 21 PSI, 80 Knots IAS

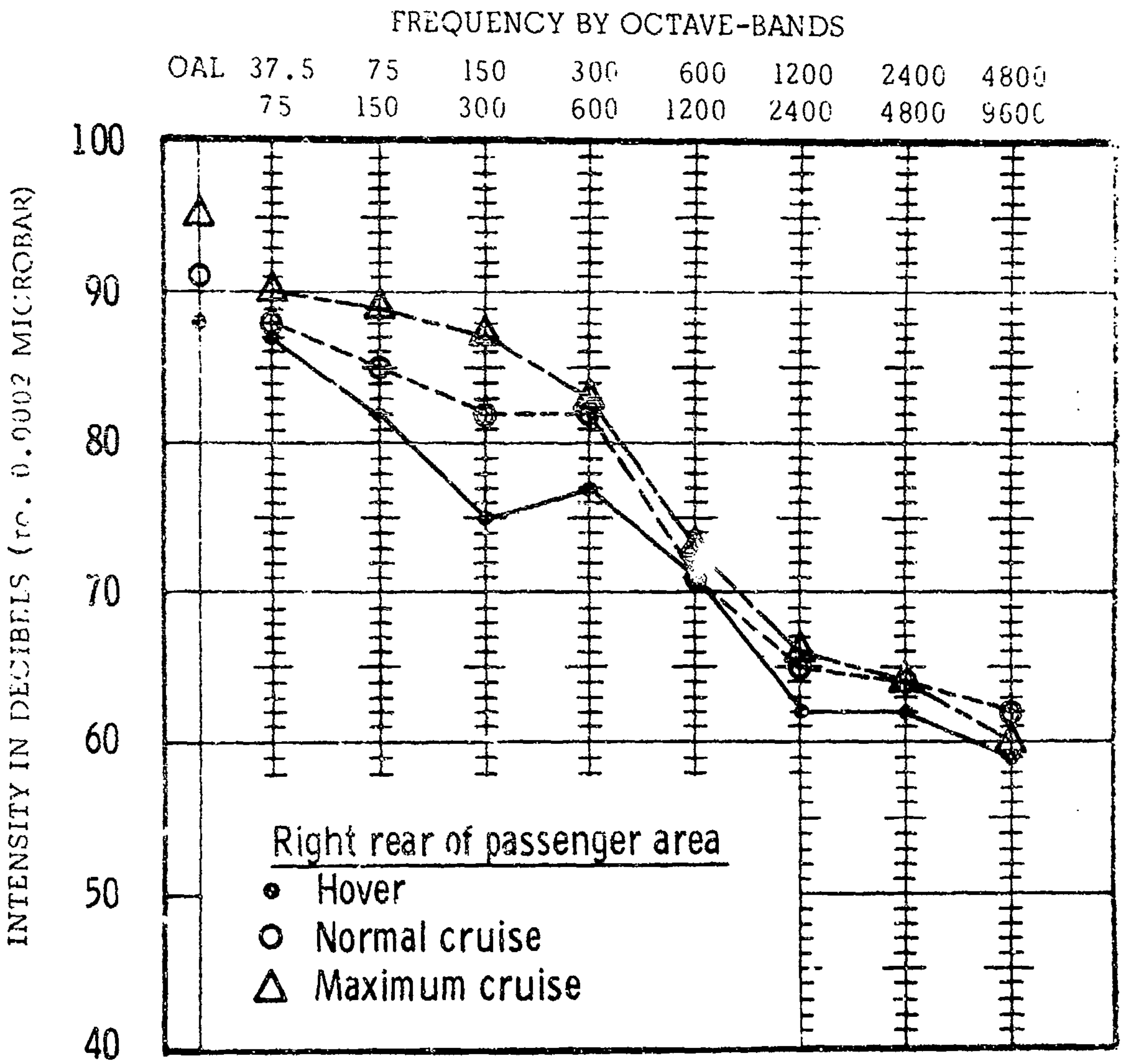

Fig. 7 Internal Noise of UH-1B Helicopter During a Hover at 24 PSI; Normal Cruise at 21 PSI, 80 Knots IAS; Maximum Cruise at 26 PSI, 100 Knots IAS

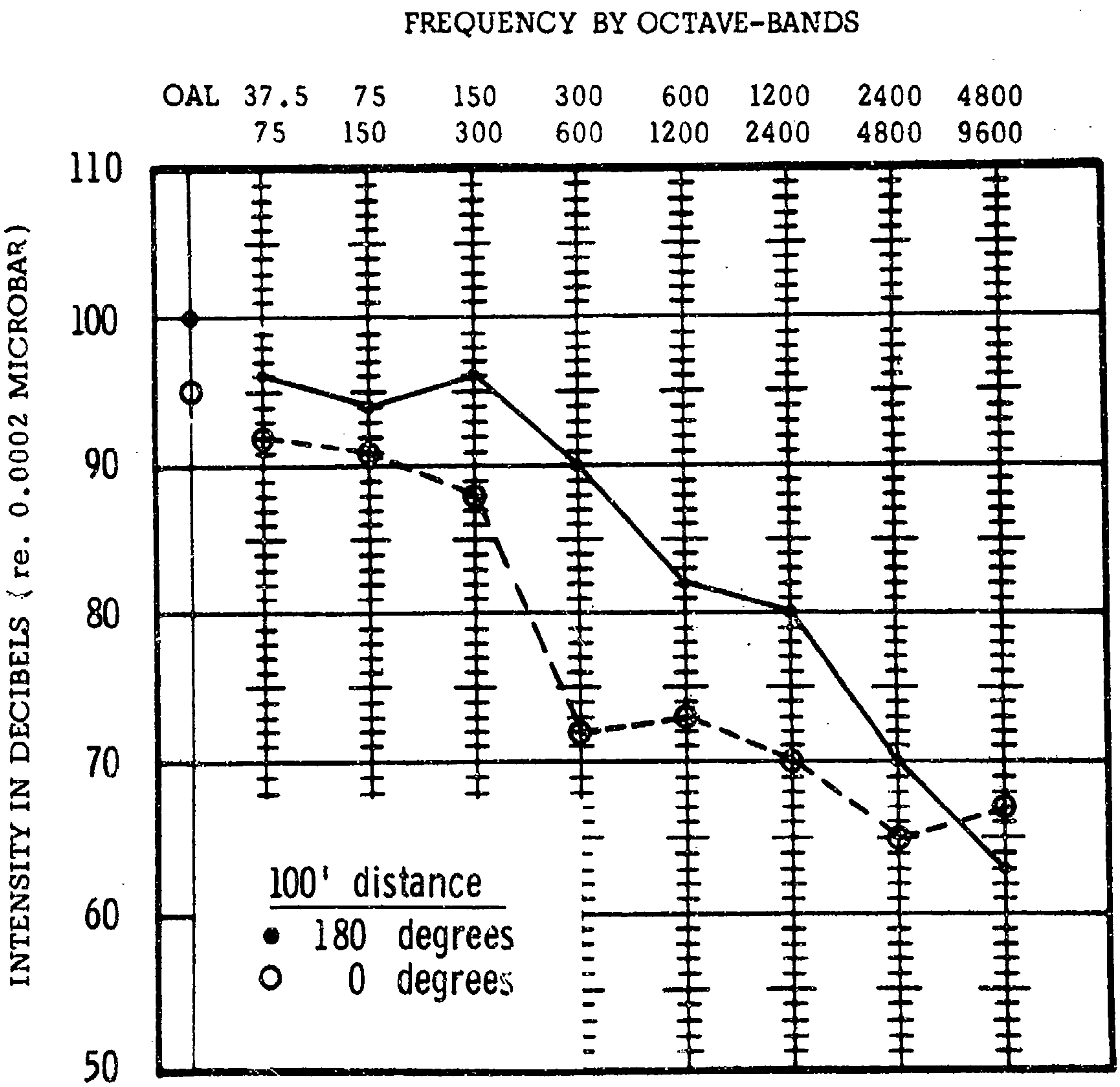

Fig. 8 External Noise of UH-1A Helicopter at a 5' Hover

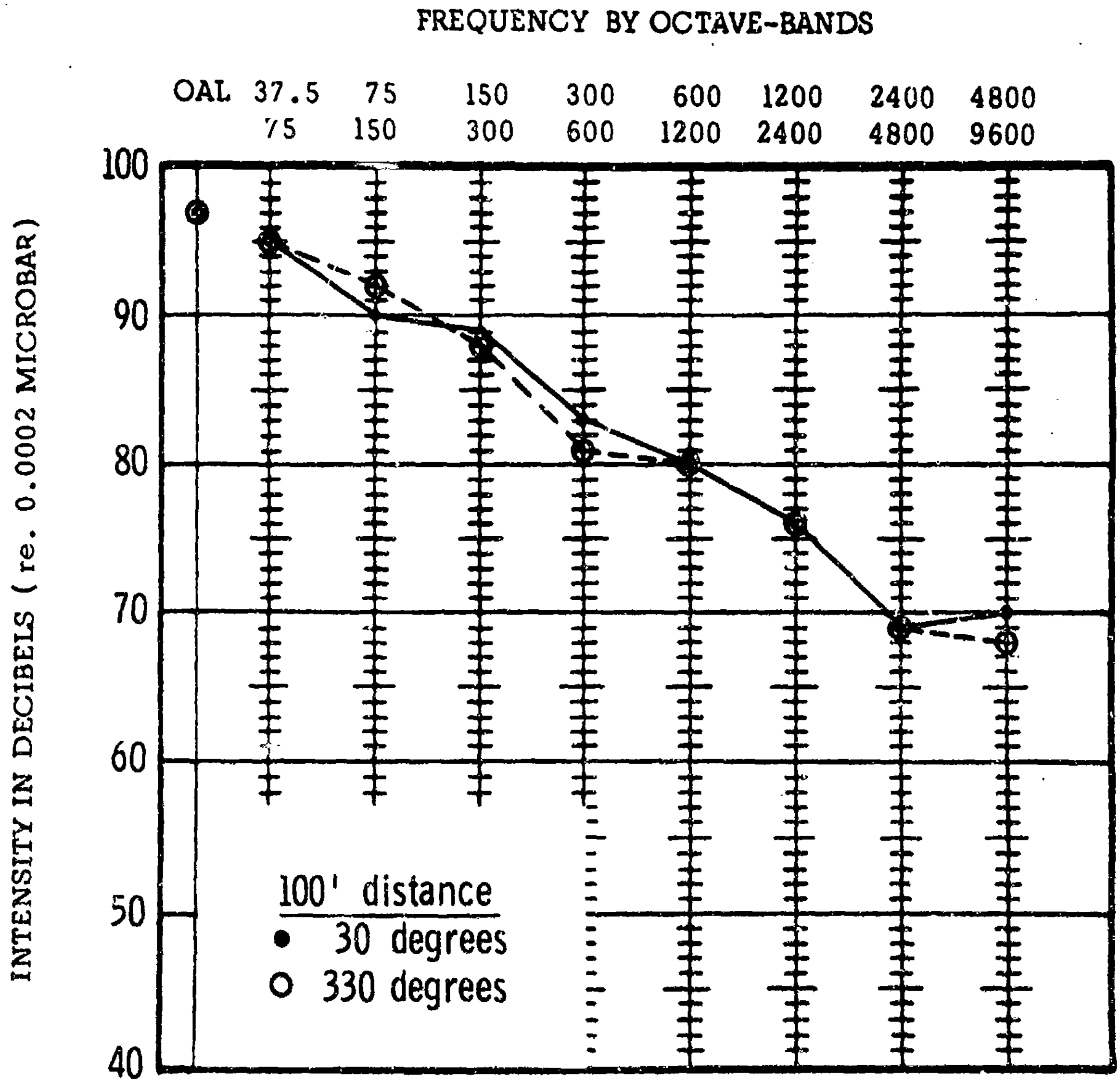

Fig. 9 External Noise of UH-1A Helicopter at a 5' Hover.

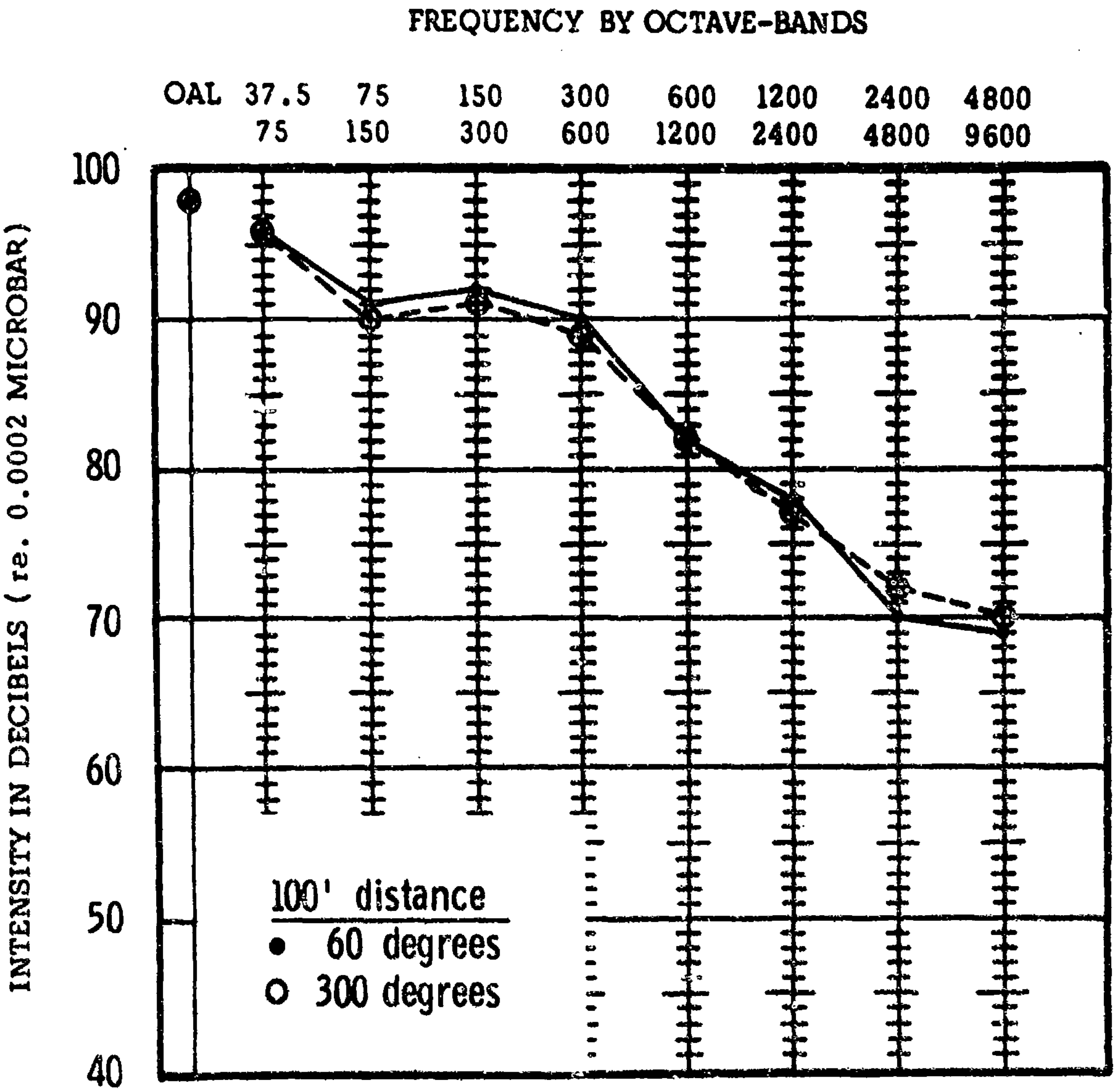

Fig. 10 External Noise of UH-1A Helicopter at a 5' Hover

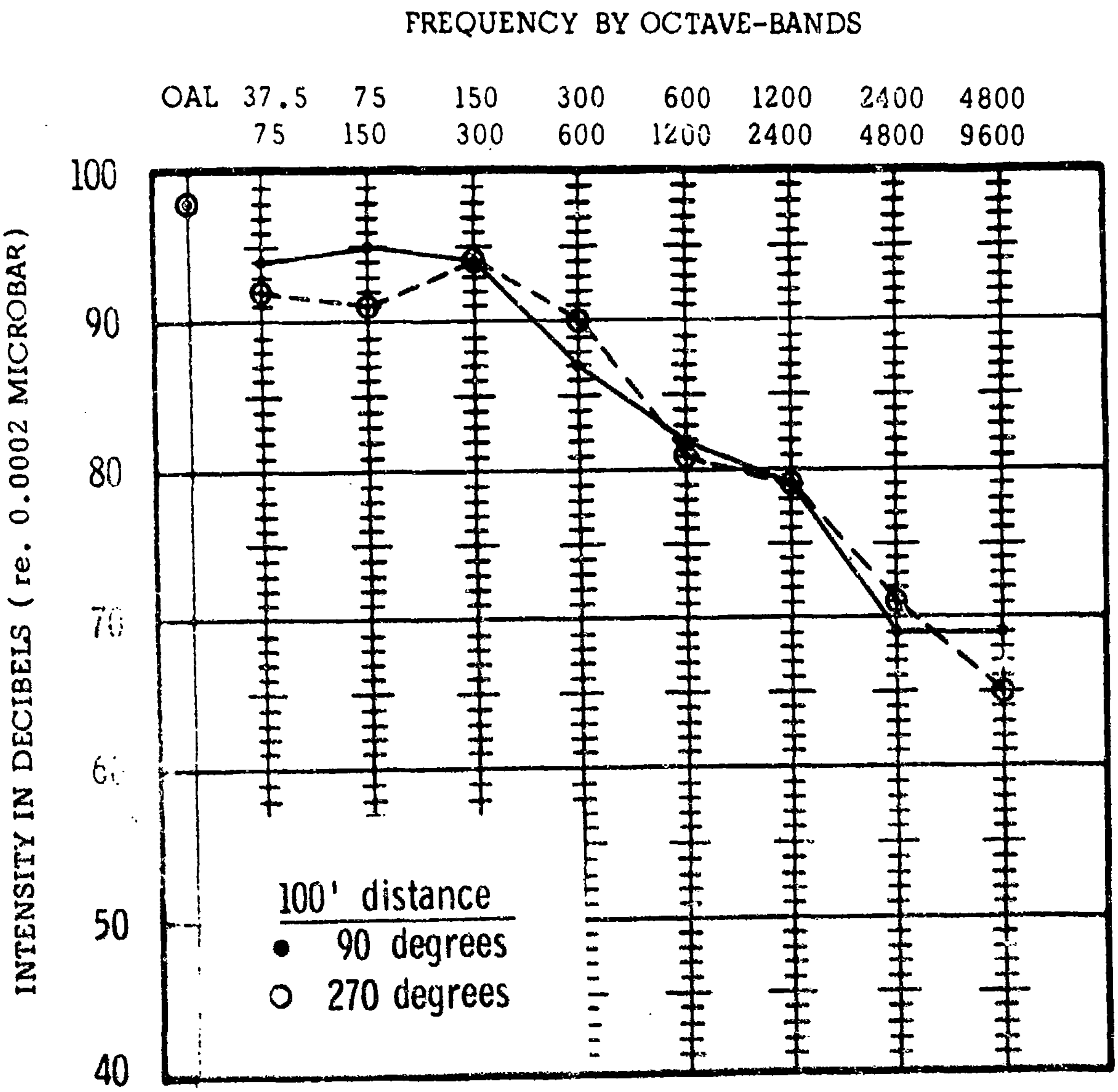

Fig. 11 External Noise of UH-1A Helicopter at a 5' Hover

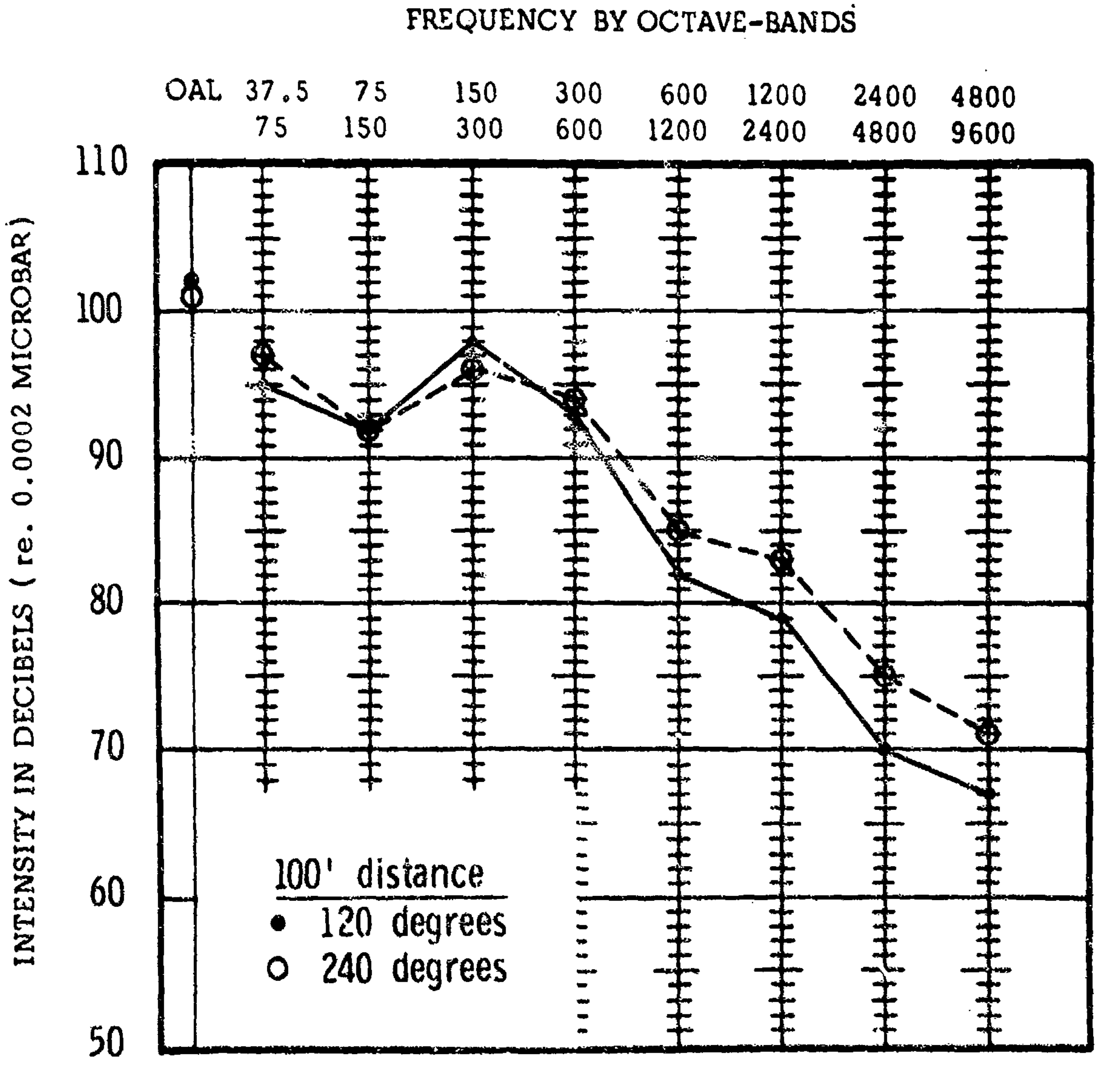

Fig. 12 External Noise of UH-1A Helicopter at a 5' Hover

OH-13H.

The OH-13H helicopter is powered by a Lycoming 0-435 in-line reciprocating engine which delivers approximately 250 brake horsepower at 3,200 rpm at maximum continuous power. The main rotor has two blades with a diameter of 35'2". The main rotor receives a total gear reduction of 9-to-1 and the antitorque tail rotor receives a gear reduction of 2-to-1.

Internal Noise: The internal noise levels of the OH-13H are basically similar during most phases of flight. One particular factor that may have a direct influence on the intensity and frequency spectrum of the internal noise is whether the cockpit doors are on or off. Due to the type of doors used on the OH-13H, they must be either on the aircraft and closed during flight, or completely removed. Usually during hot weather the doors are removed and during cold weather operation the doors are usually attached and closed. Figure 13, page 23, illustrates the amount of internal noise generated within the OH-13H during ground and hover maneuvers (doors on and doors removed). Figure 14, page 24, shows noise generated at the head level of the left occupant in the OH-13H during a cruise at 500 feet altitude and at 55 knots (IAS). During this maneuver the engine was operating at 3,200 rpm and 22 inches of manifold pressure. The main rotor had a blade passage frequency of 11.9 times per second and a tip speed of 656.1 feet per second (0.587 Mach). The antitorque rotor had a blade passage frequency of 53.3 times per second and a tip speed of 477.6 feet per second (0.427 Mach).

External Noise: During ground operations the OH-13H produces noise exposures that are characteristic of helicopters powered by small reciprocating engines. The following noise plottings illustrate noise exposures at positions of 100 feet distance from the aircraft. During these measurements the engine was operating at 3,100 rpm and the aircraft was maintaining a three foot hover. The locations are at equal angular positions on the right and left sides of the helicopter. For instance, 90 degrees and 270 degrees refer to positions directly at the sides of the helicopter; the right side being 90 degrees and the left side being 270 degrees. During these measurements the main rotor had a blade tip velocity of 635.8 feet per second and the tail rotor 462.7 feet per second.

Figure 15, page 25, shows plottings of noise measurements taken directly to the front and rear of the helicopter. The locations aft of the helicopter contain the most intense noise exposures. During a hover, considerable torque is applied to the blades. This torque, together with rotational and vortex type noise produced by the tail rotor and the noise emanating from the exhaust of the engine, combine to produce a louder noise exposure at locations at the rear than at the front of the helicopter. Figure 16, page 26, illustrates the noise generated at locations 30 degrees

from the front of the aircraft on the right and left sides. The influence of antitorque rotor noise is most evident at the position on the left side of the helicopter (330 degrees). Also, at this position the noise spectrum tends to contain higher frequency components than at locations to the front and rear of the helicopter during similar power operations. Figure 17, page 27, shows results of noise measurements completed at locations 60 degrees on both the right and left sides of the helicopter. The noise levels and the spectrum plottings indicate that the noise generated by the various components are relatively equal at these two locations. Figure 18, page 28, shows noise measurements made at locations directly to the right and left side of the helicopter. The position on the left side of the helicopter still indicates the presence of noise from the antitorque rotor system. At a location further to the rear of the aircraft, as shown in Figure 19, page 29, the presence of antitorque rotor noise becomes even more evident. The aft locations represent a complex mixture of rotor, antitorque rotor, gear-distribution shaft, and engine exhaust noise components. The noise generated by the antitorque rotor is quite evident, especially at frequencies above 600 cps. In Figure 20, page 30, the noise spectrum is altered due to noise elements emanating from the main rotor and the engine exhaust. Noise emanating from the antitorque rotor is only slightly noticeable in the noise plottings, but is still subjectively audible.

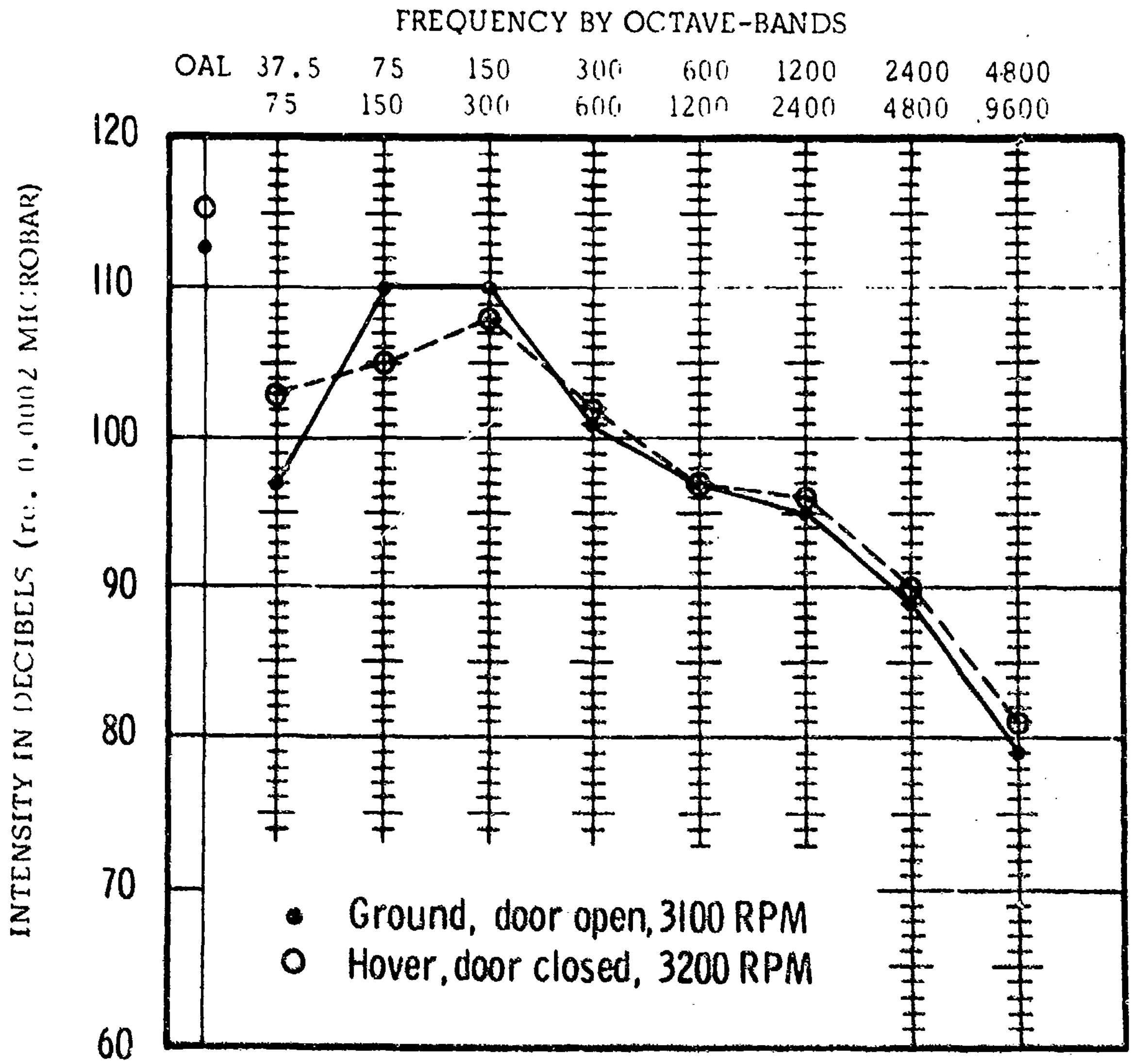

Fig. 13 Internal Noise of OH-13H Helicopter During Ground Operations and a 3' Hover

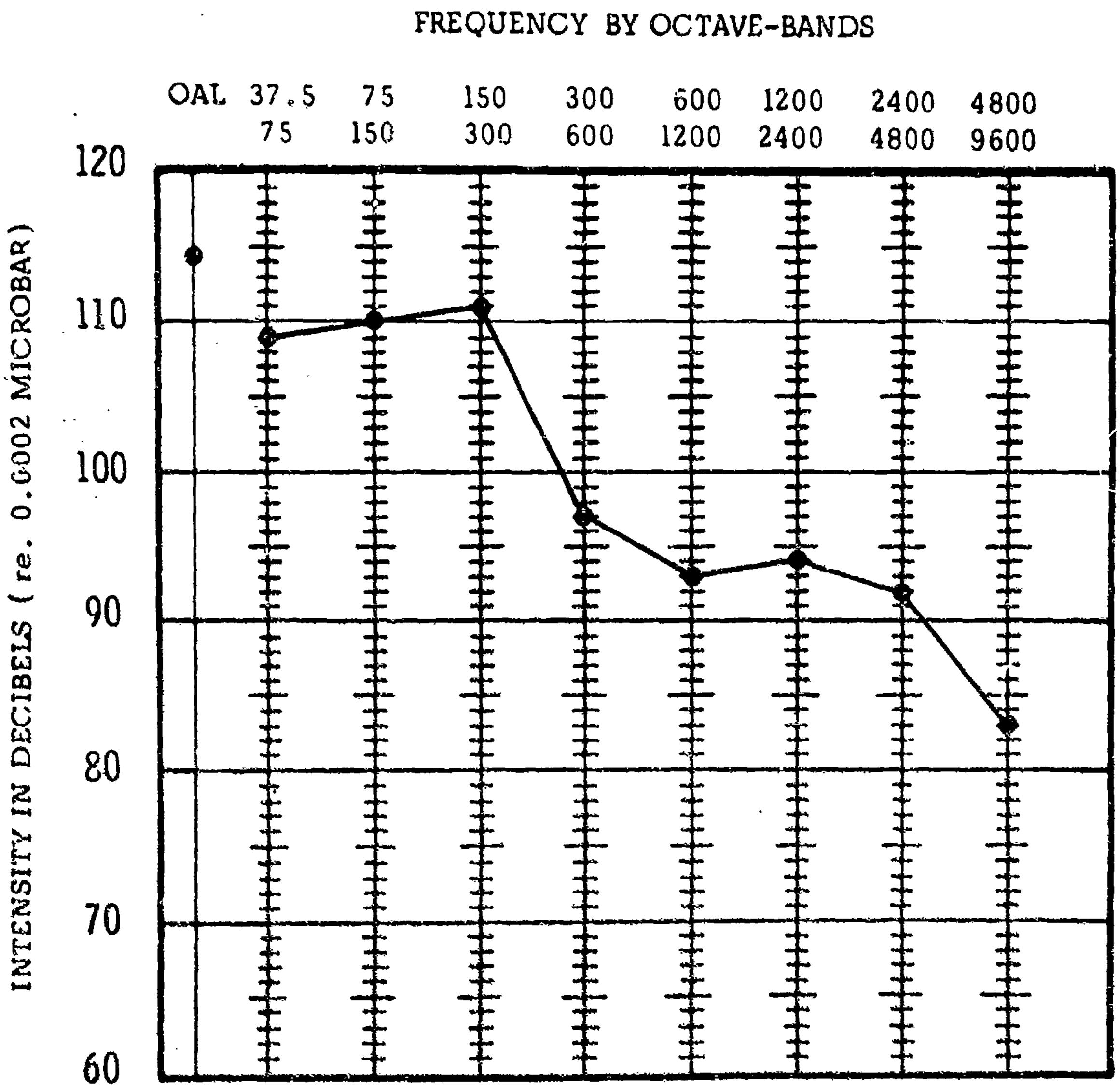

Fig. 14 Internal Noise of OH-13H Helicopter During Normal Cruise at 500' Altitude, 3100 RPM, 22" MP, 55 Knots IAS

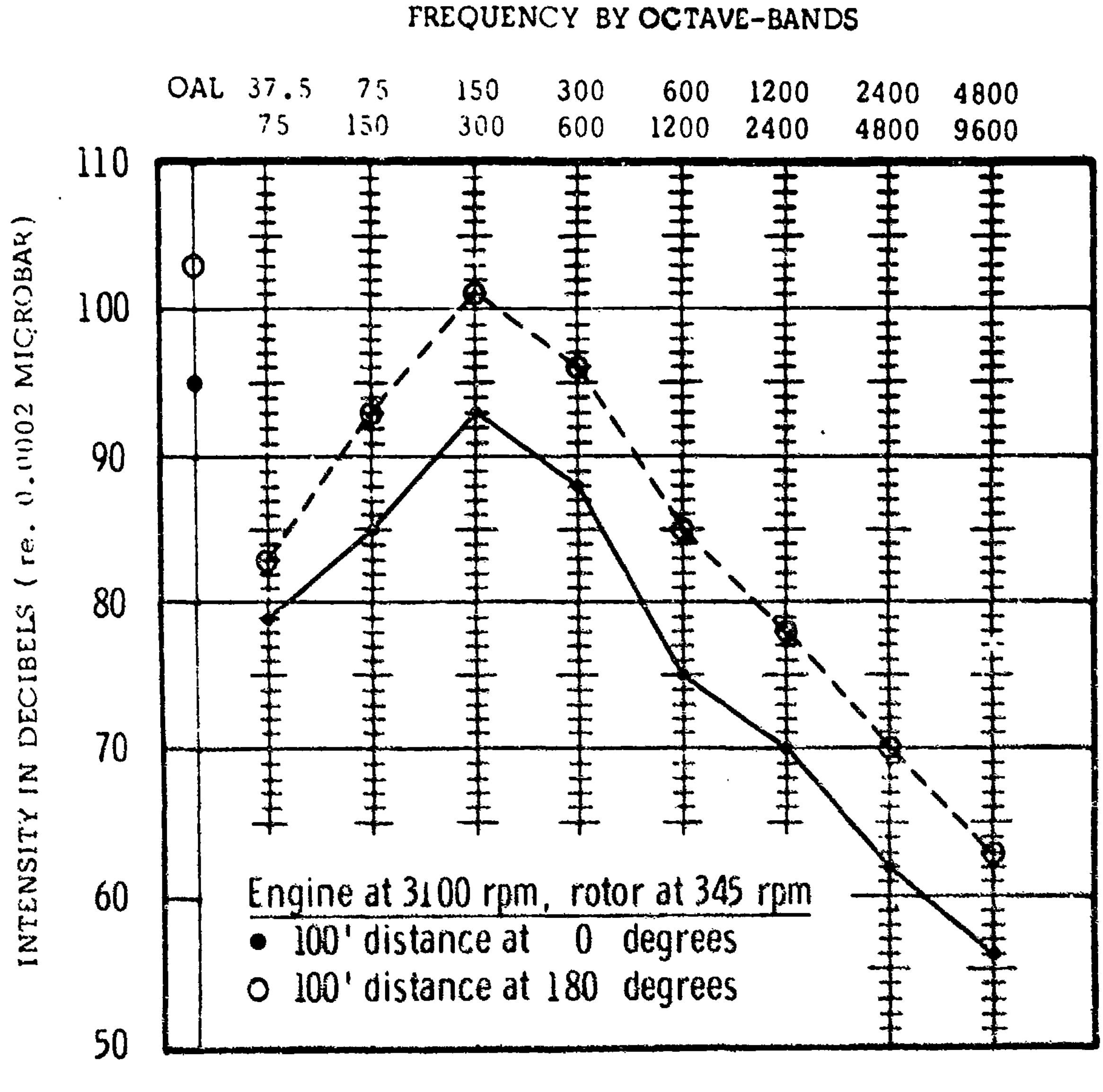

Fig. 15 External Noise of OH-13H Helicopter at a 3' Hover

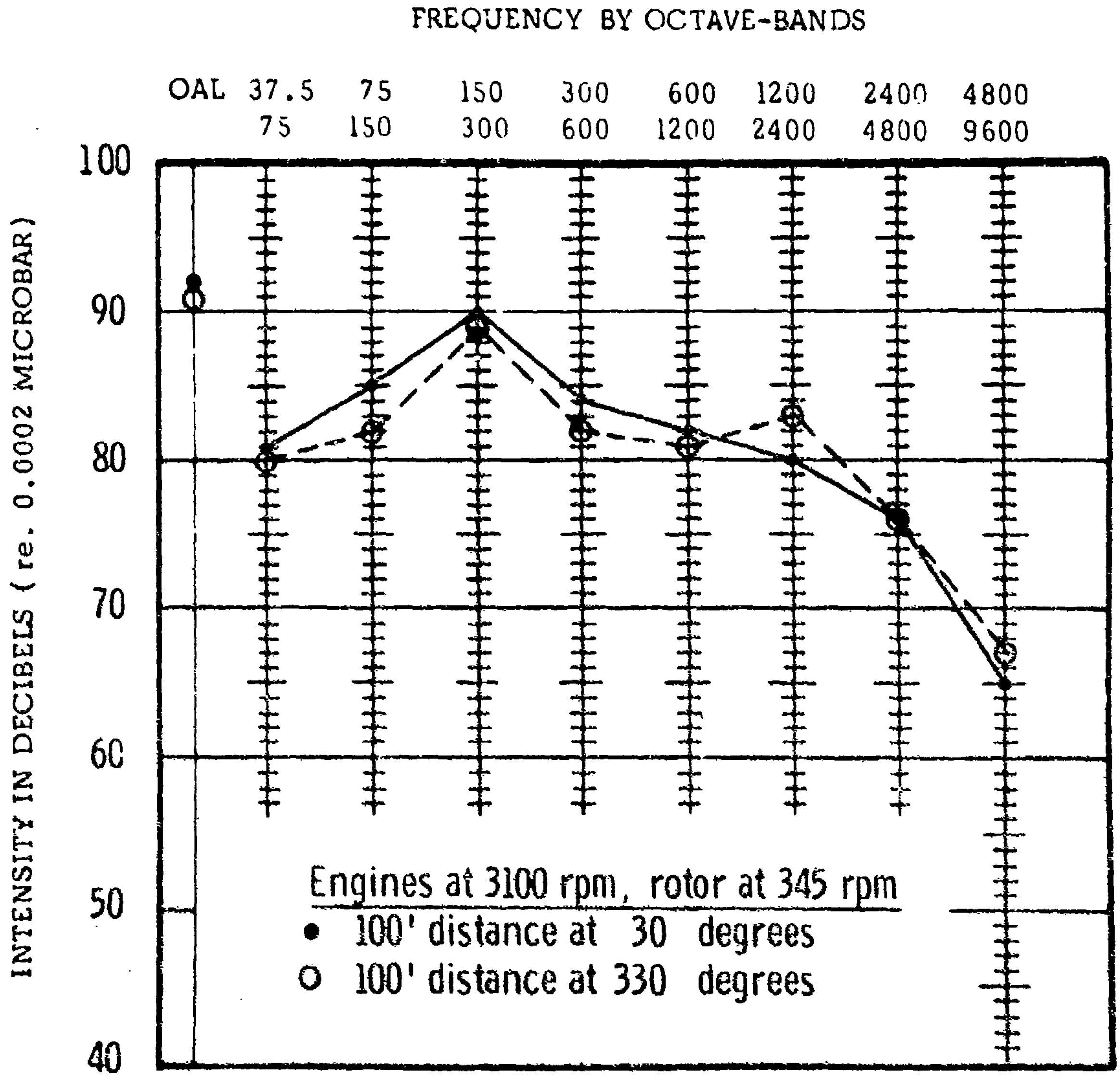

Fig. 16 External Noise of OH-13H Helicopter at a 3' Hover

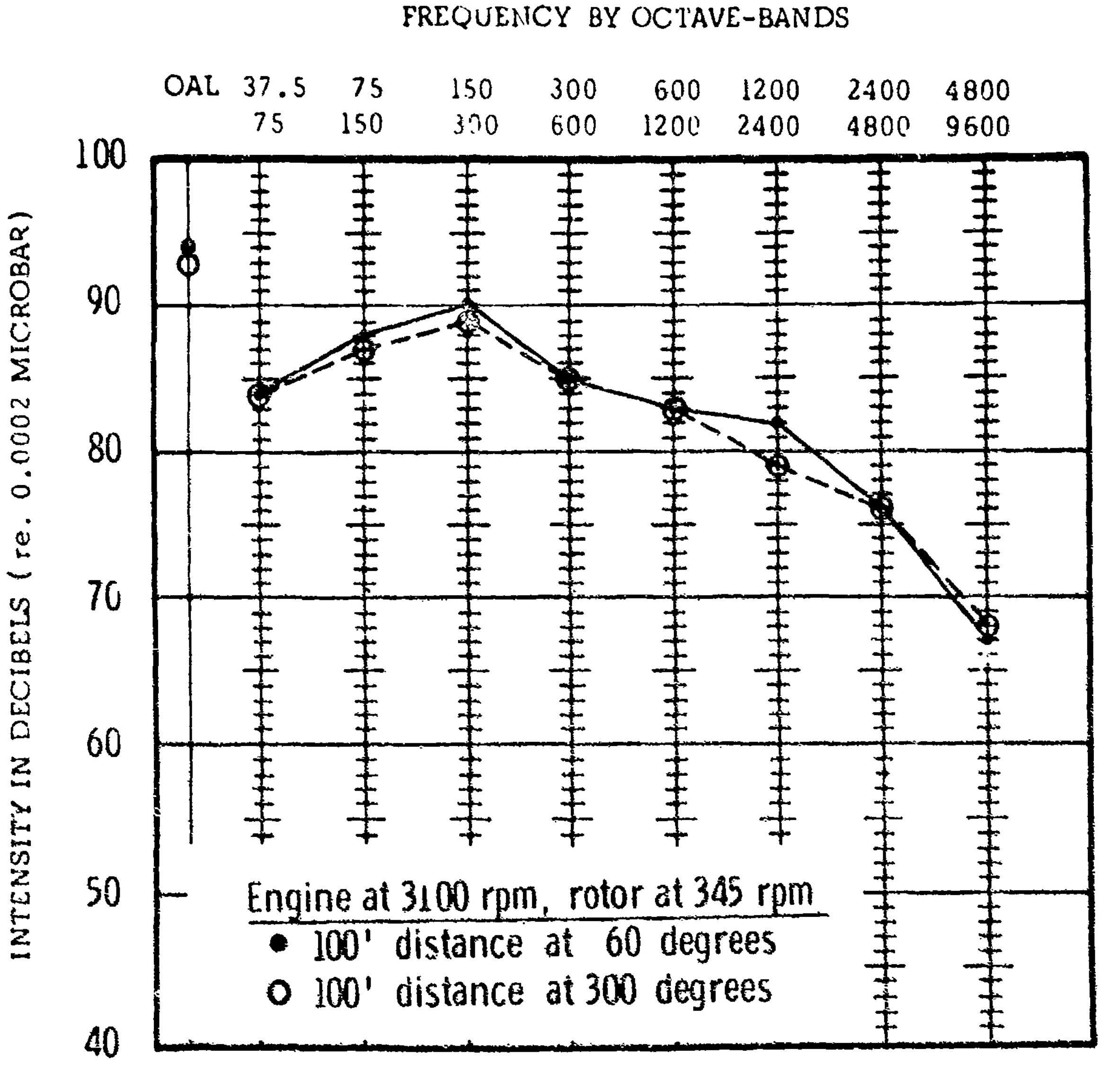

Fig. 17 External Noise of OH-13H Helicopter at a 3' Hover

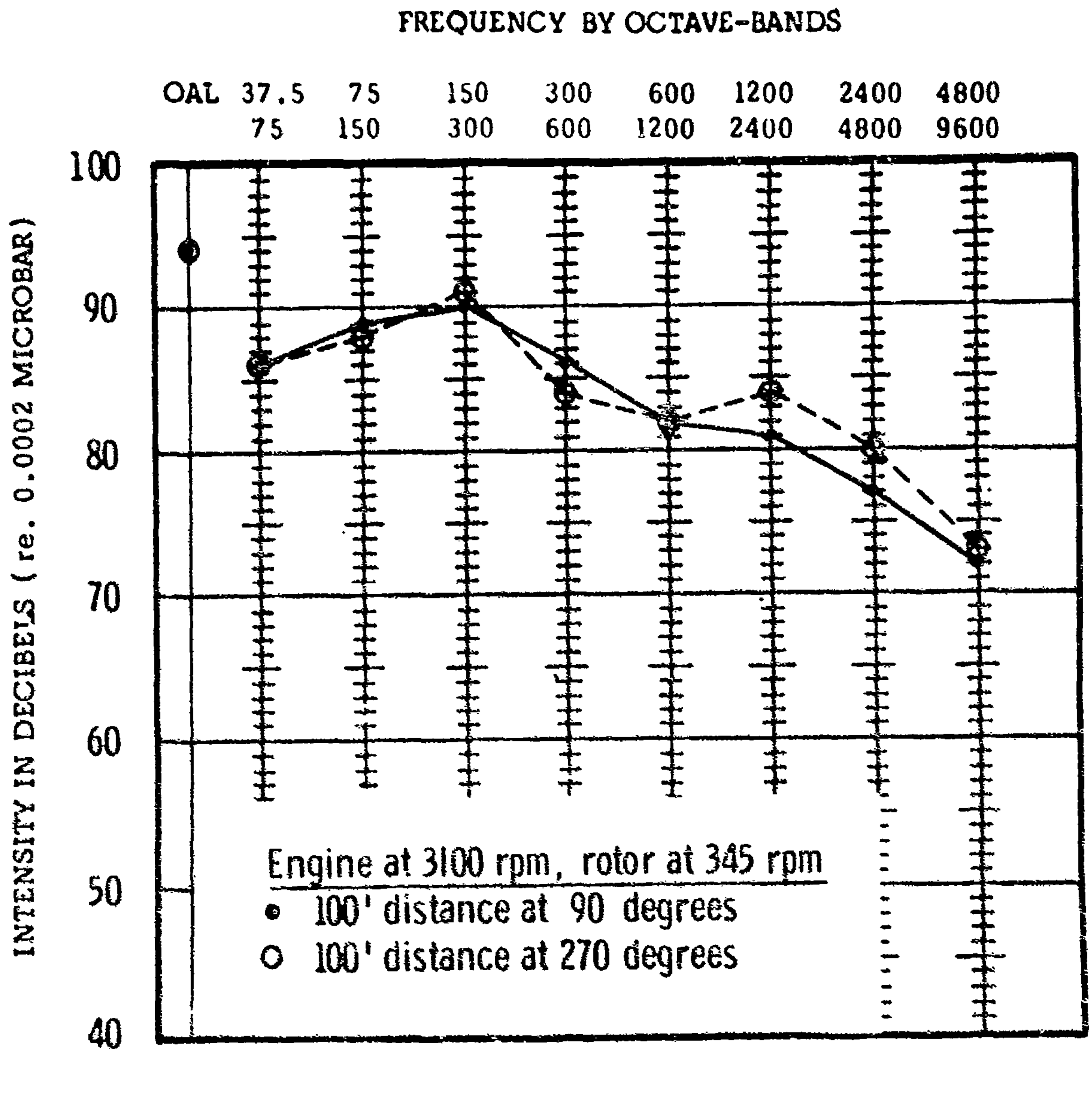

Fig. 18 External Noise of OH-13H Helicopter at a 3' Hover

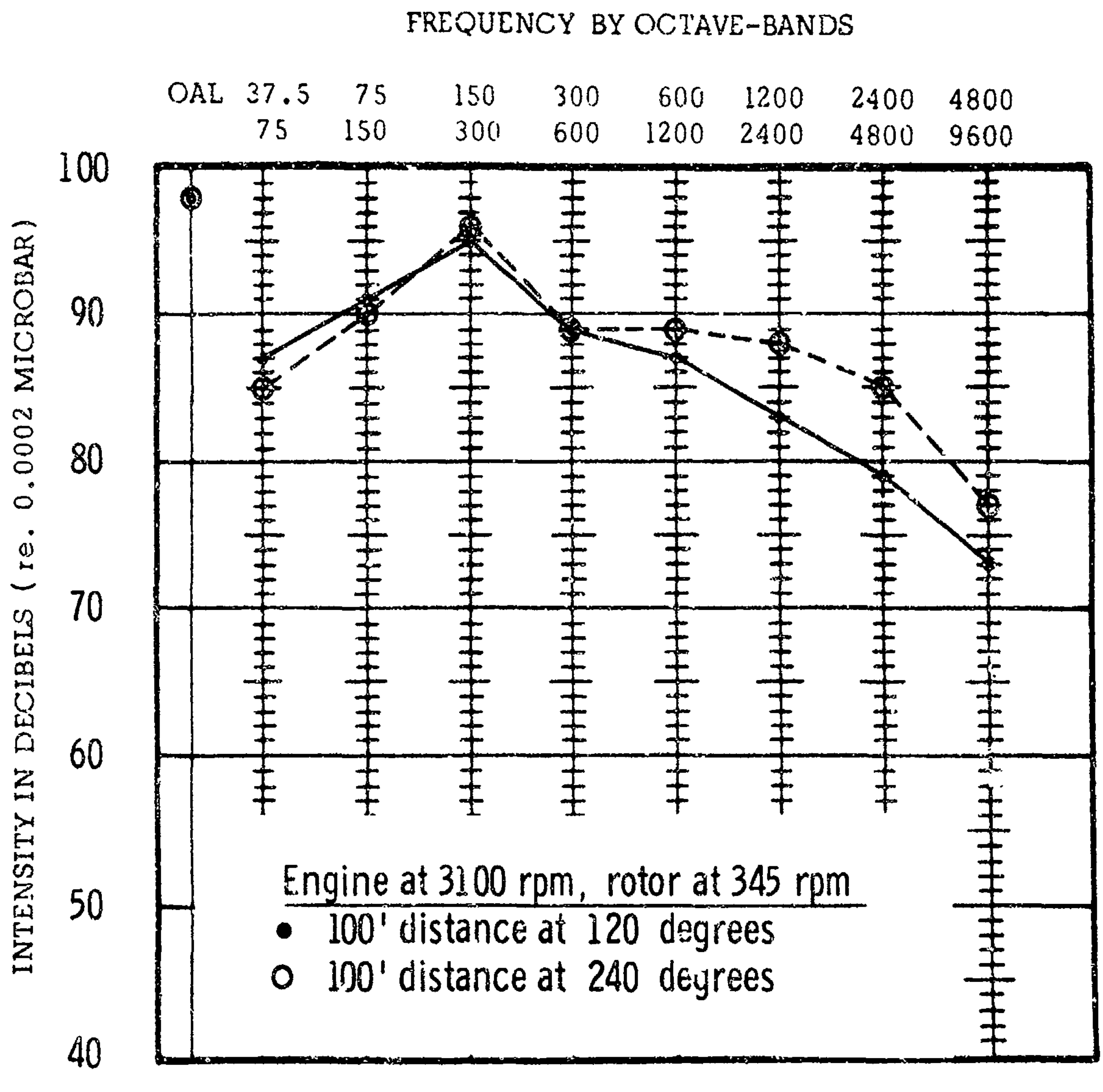

Fig. 19 External Noise of OH-13H Helicopter at a 3' Hover

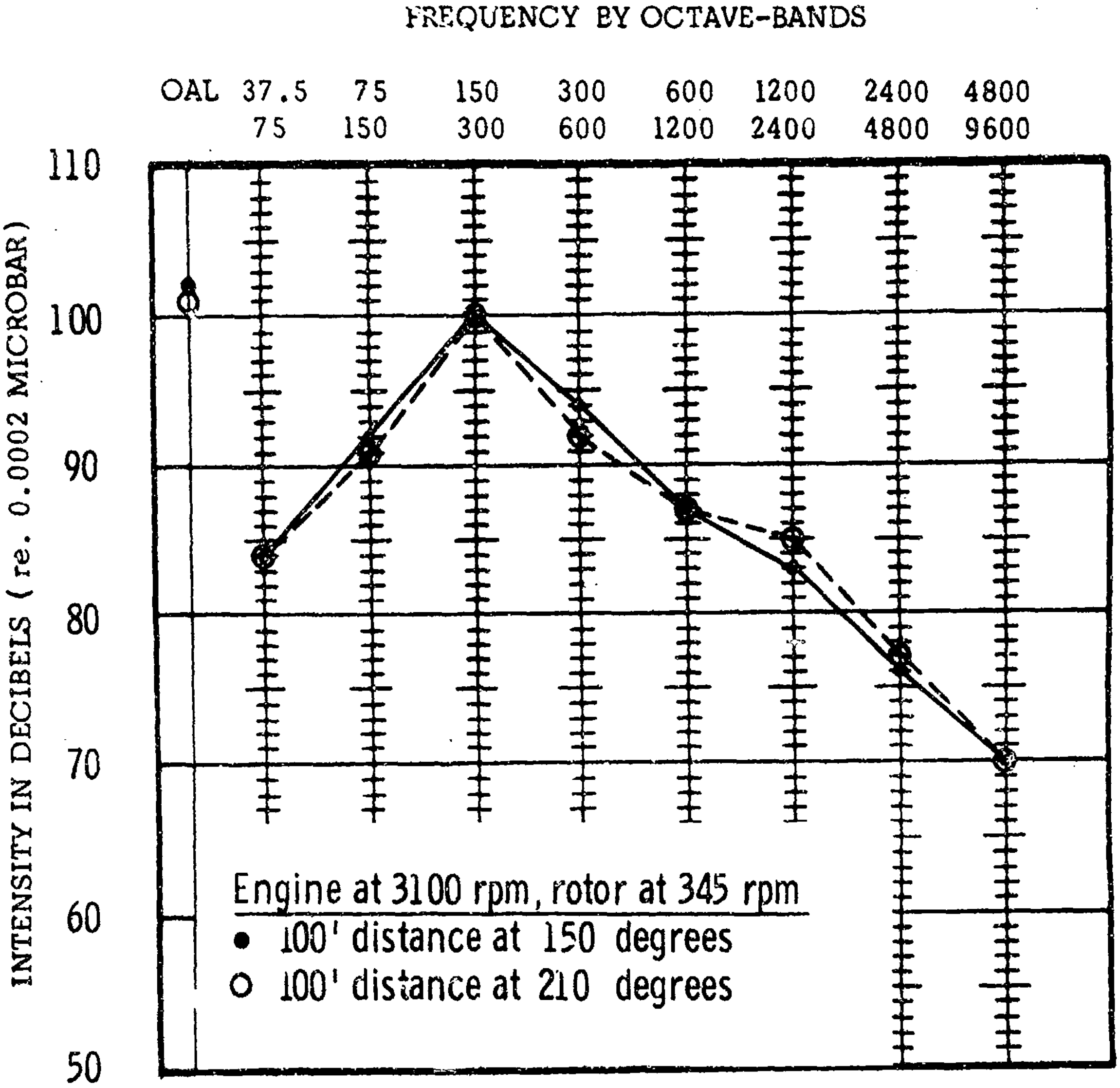

Fig. 20 External Noise of OH-13H Helicopter at a 3' Hover

UH-19D.

The UH-19D is a utility type helicopter that has a passenger-cargo compartment located below and aft of the cockpit area. The cockpit is arranged in such a manner that the engine is beneath and in front of the pilot compartment with a torque-distribution shaft running from the engine to the transmission unit which is located behind the pilot compartment and above the forward section of the passenger-cargo area. The shaft-distribution unit from the engine goes between the pilots, and this shaft rotates at a speed equal to that of the engine shaft. Primary gear reduction takes place at the main transmission unit and not within the engine itself.

The UH-19D is powered by a single Pratt and Whitney R-340 radial type reciprocating engine which produces approximately 800 brake horsepower at 2,600 rpm for maximum continuous engine operation and a high normal power of 700 brake horsepower at 2,400 rpm. The engine has a single exhaust port that opens on the lower left side of the forward cowling of the engine.

The UH-19D has a single three-blade main rotor which has a diameter of 53'0" and a two-blade tail antitorque rotor that has a diameter of 8'9". The main rotor receives a total gear reduction of 11.3-to-1 and the tail rotor receives a reduction of 1.62-to-1.

Internal Noise: The following noise plottings show results of noise measurements taken at various locations within a UH-19D helicopter during various flight conditions. Figure 21, page 34, illustrates the noise exposure produced at three different internal locations during ground idle. Noise emanating from two sources, the transmission and the engine exhaust, are more pronounced within the pilot compartment. Exhaust noise and rotor noise contribute to the total acoustical energy present in the 37.5 through 75 cps octave band, and the transmission and torque-distribution shaft contributes to the increased noise present in the frequency range above 4800 cps. Figure 22, page 35, illustrates plottings of noise measurements completed at similar locations with the engine of the aircraft operating at a higher power setting. In this instance, the transmission and engine shaft noise is still present, but is being masked by the over-all increase in the noise generated by the engine exhaust and rotors. The noise generated within the helicopter indicates an increase in the higher frequency bands as the over-all engine power increases. In Figure 23, page 36, the helicopter is maintaining a hover and noise emanating from the main rotor, transmission, and engine exhaust are most pronounced. Increased engine torque and increased rotor blade loadings account for the increased noise levels within the 75 through 150 and 600 through 1200 cps octave bands. The influence of airspeed and rotor disturbances on the noise level changes are shown in Figure 24, page 37, and Figure 25, page 38. During normal cruise the airspeed was 75 knots (IAS) and during high cruise, 95 knots

(IAS). The presence of transmission noise is quite evident during normal cruise, especially within the pilot compartment. At high cruise the transmission noise becomes somewhat less noticeable due to an increase in the noise emanating from the main rotor. Noise emanating from the main rotor is directly influenced by increased blade loadings and pitch, as well as increased forward airspeed. During both conditions, normal and high cruise, the rotor blade tips were rotating at the same velocity of 589.0 feet per second (0.528 Mach) and the determiner of noise was primarily blade torque.

Figure 26, page 39, shows results of noise measurements made in the center line of a UH-19D during three types of power and flight conditions. During low ground idle, the noise generated by the torque-distribution shaft that passes from the engine to the transmission unit (located behind the pilot compartment) is most evident at 2400 to 4800 cps. During high power ground operation, the noise produced by increased engine torque tends to mask transmission noise. During a hover, the high torque applied to the transmission system produces a distinct change in the character of the noise emanating from the transmission (the transmission noise is now most pronounced in the 600 to 1200 cps frequency band). This alteration is caused by an increase in intense engine noise which tends to mask the less intense shaft-distribution noise. Basically, noise in the 75 to 150 cps octave band is a mixture of exhaust, the first (main) stage transmission system, and rotors. Figure 27, page 40, illustrates the relatively even distribution of noise generated within the UH-19D at different internal locations, including the pilot compartment and the passenger-cargo area. The range of total intensities, measured within the eight octave bands from the lowest to the highest levels recorded, are shown. As indicated, the range representing the greatest difference within the eight octave bands is found at frequencies above 1200 cps. Figure 28, page 41, has been similarly prepared to show the lowest-to-highest ranges of noise produced within the eight octave bands during three powered flight conditions. The top lines (vertical) represent the range of noise levels generated during a hover. The middle area (lines slanting to the right) represent the range of noise levels recorded during maximum cruise conditions, and the lower area (lines slanting to the left) represent noise levels recorded during normal cruise. The various plottings were established by taking the lowest-to-highest noise levels recorded at locations measured in the pilot compartment and the passenger-cargo area of the helicopter.

External Noise: In most instances, the over-all external noise levels produced by the UH-19D are directly influenced by the engine exhaust. The engine has a single exhaust port which empties the exhaust gases from the forward left area of the engine cowling. Therefore, the noise produced by the engine exhaust will be most intense at locations near the left side of the helicopter. Figure 29, page 42, shows results of noise measured at a distance of 100 feet from the center of the aircraft

during a hover with the engine operating at 2,400 rpm and at 34 inches of manifold pressure. The blades of the main rotor were rotating at a blade passage frequency of 10.6 times per second and a blade tip velocity of approximately 589.4 feet per second (0.528 Mach). The tail rotor was rotating at a tip velocity of 690.4 feet per second (0.618 Mach) and a tail rotor blade passage frequency of 49.4 times per second. The noise levels recorded at the side of the helicopter (90 degrees) demonstrated the influence of exhaust and antitorque tail rotor noise. The increases in the frequency ranges above 1200 cps are characteristic of this type of noise.

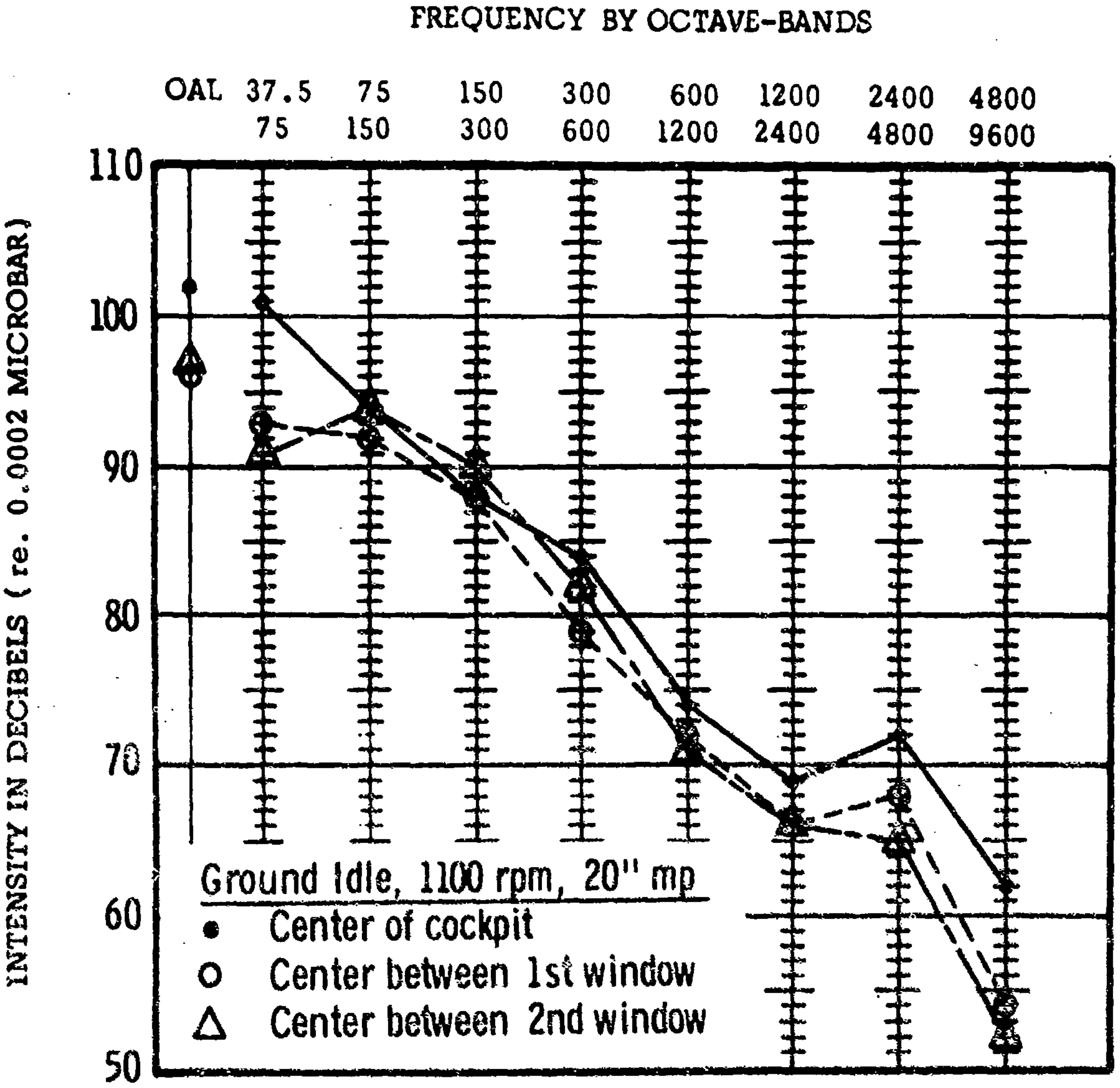

Fig. 21 Internal Noise of UH-19D Helicopter During Ground Idle Operations

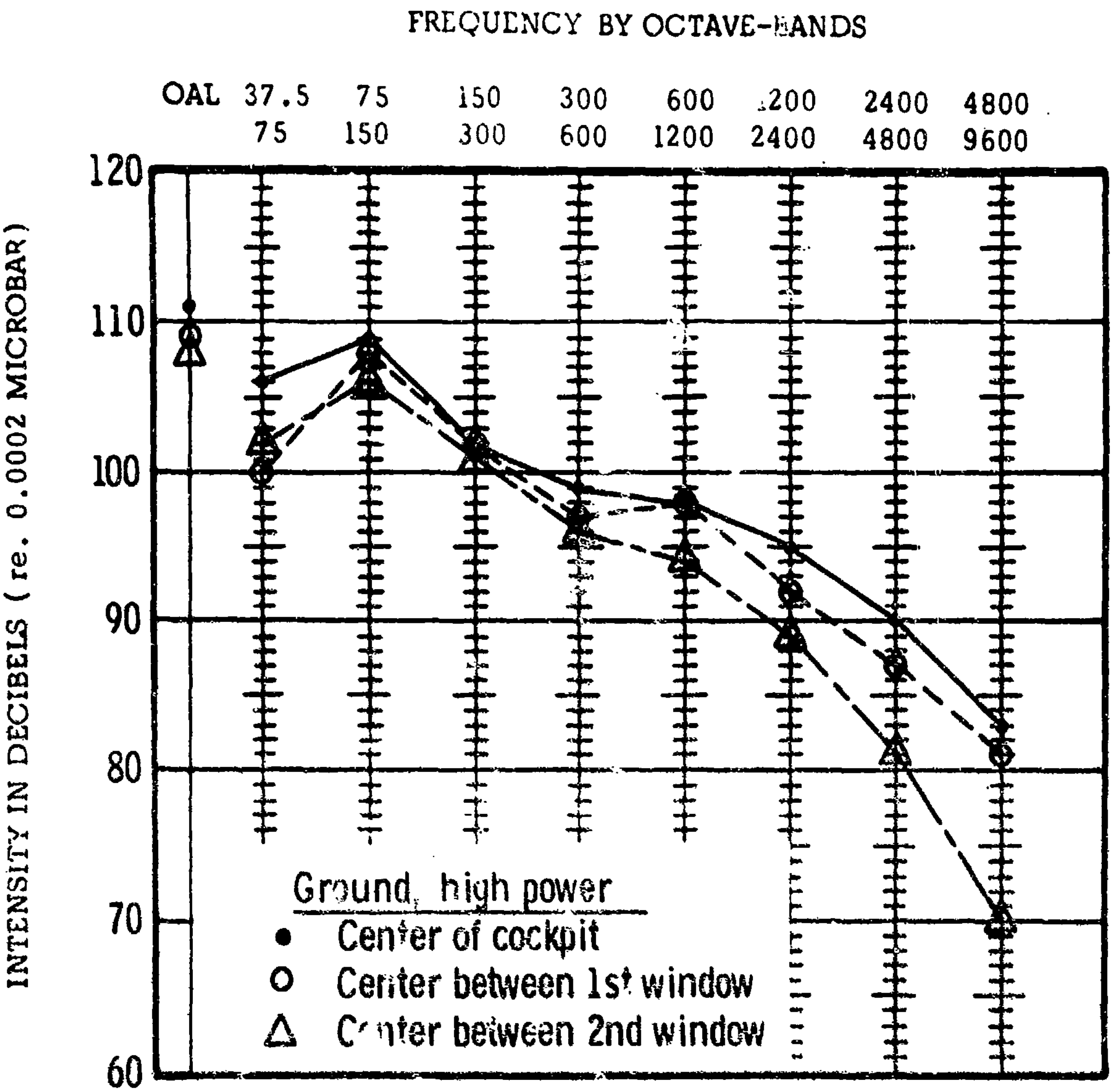

Fig. 22 Internal Noise of UH-19D Helicopter During Ground Operations, 2400 RPM, 24" MP

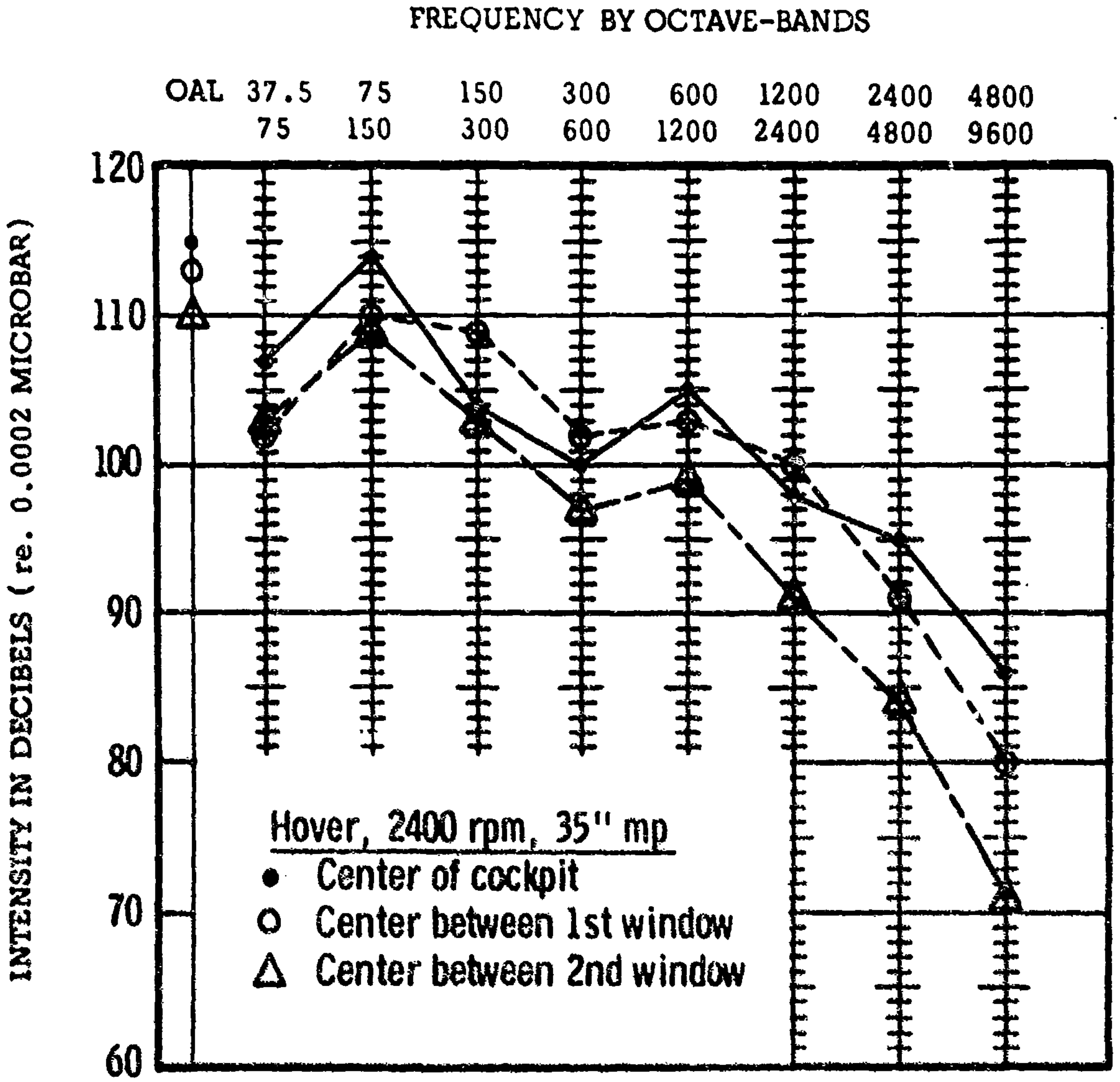

Fig. 23 Internal Noise of UH-19D Helicopter at a 5' Hover

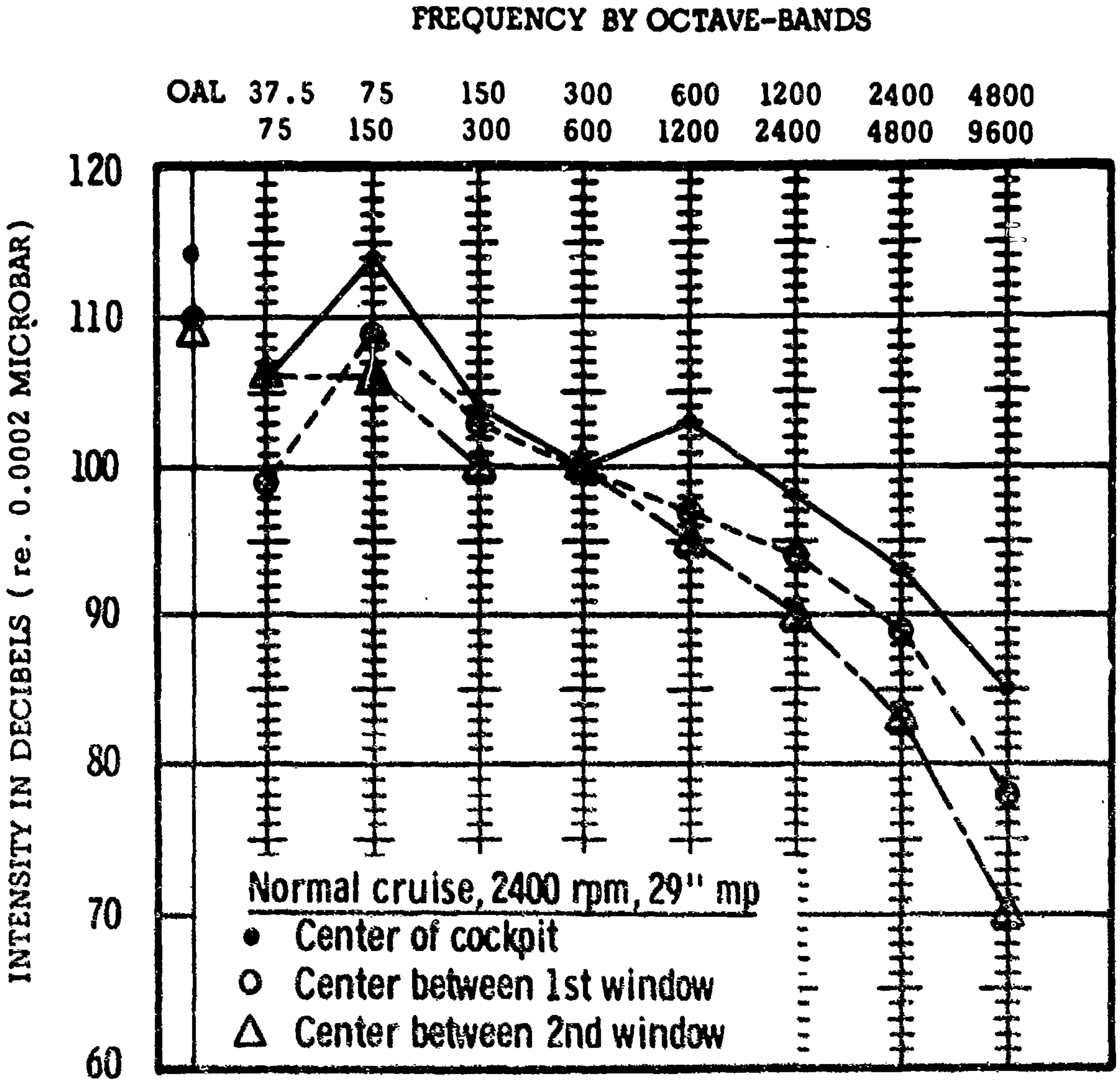

Fig. 24 Internal Noise of UH-19D Helicopter During Normal Cruise at 500' Altitude, 75 Knots IAS

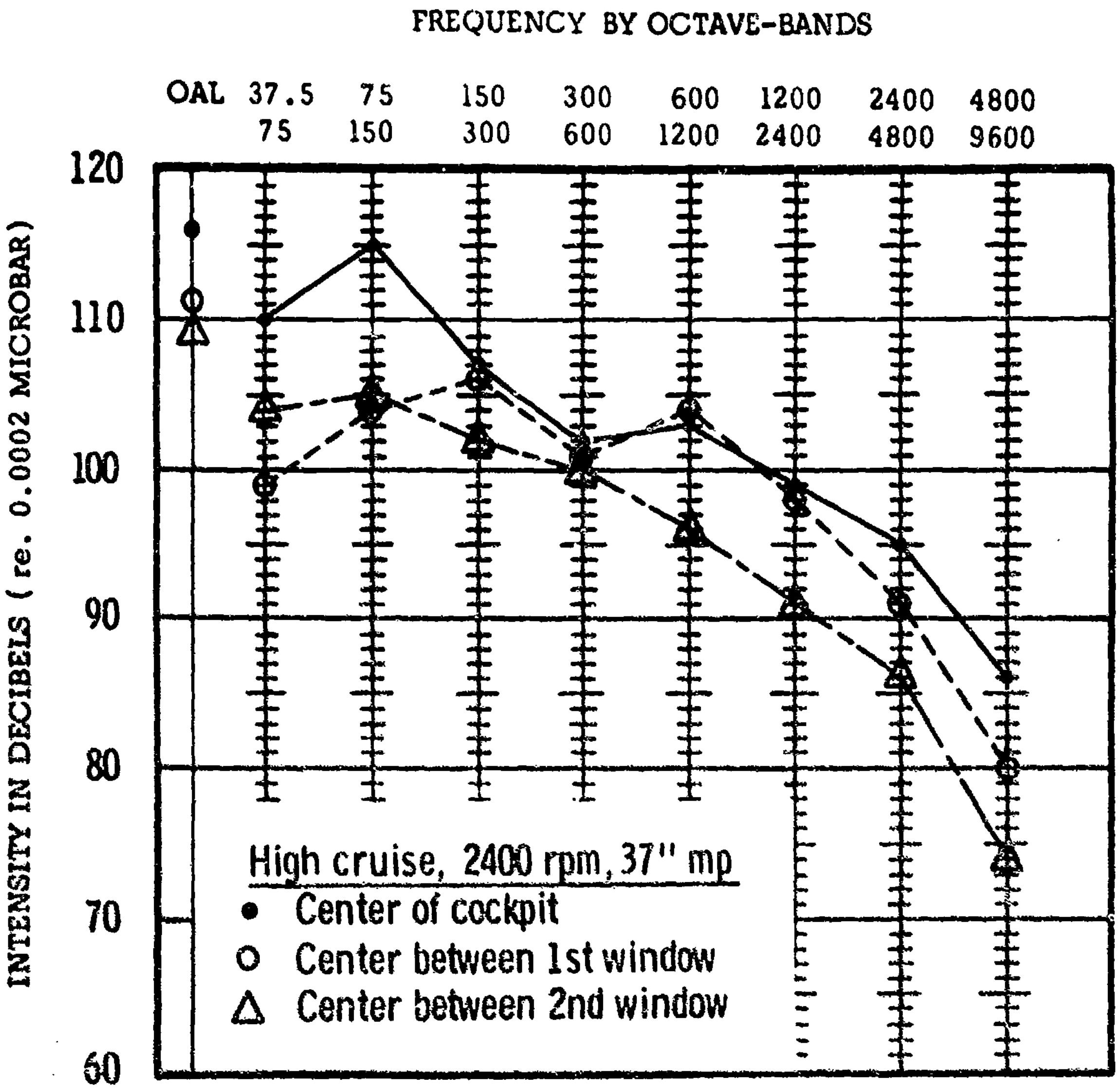

Fig. 25 Internal Noise of UH-19D Helicopter During Maximum Cruise at 500' Altitude, 95 Knots IAS

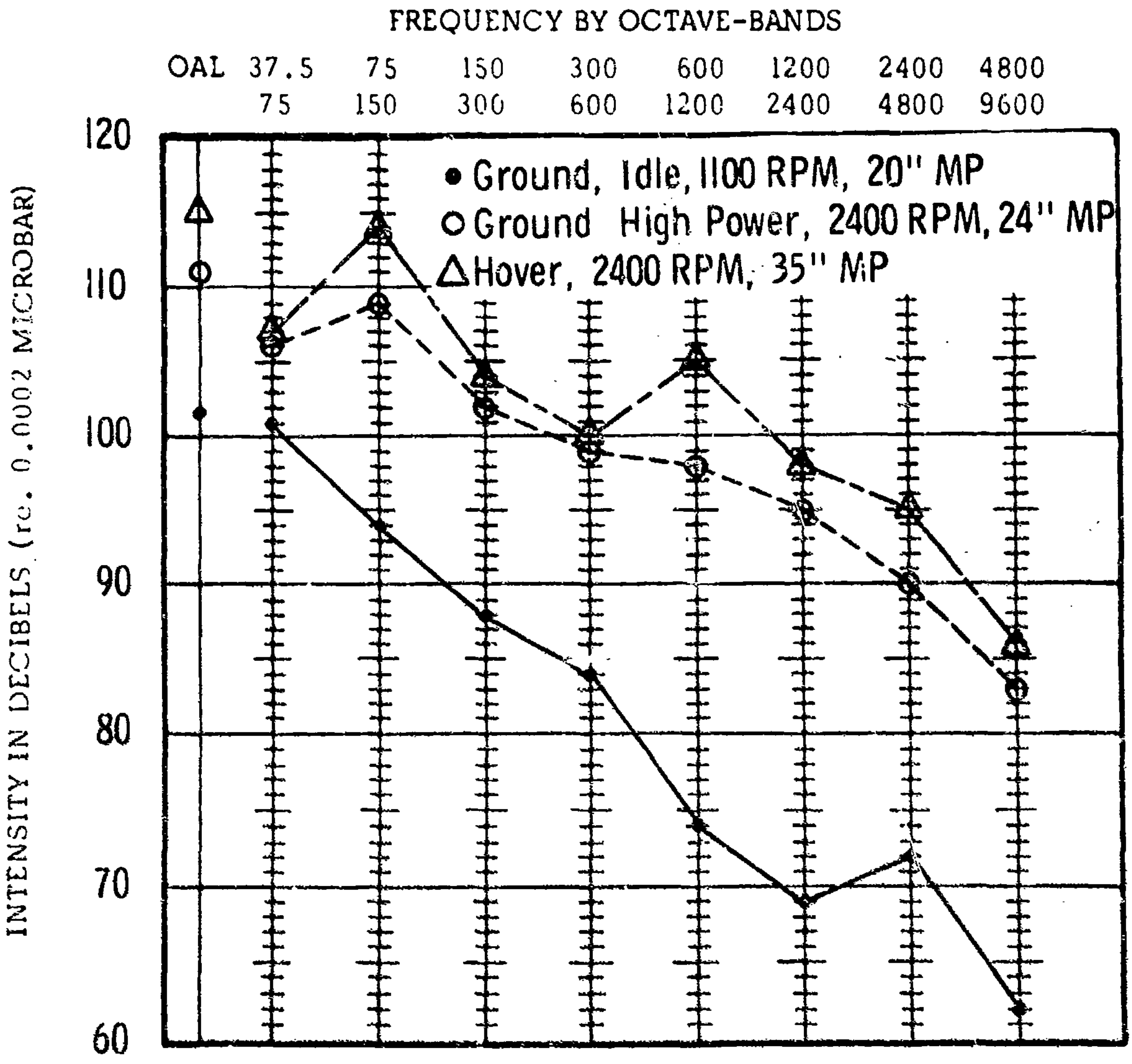

Fig. 26 Internal Noise of UH-19D Helicopter During Ground Idle, Ground Operations, and a 5' Hover

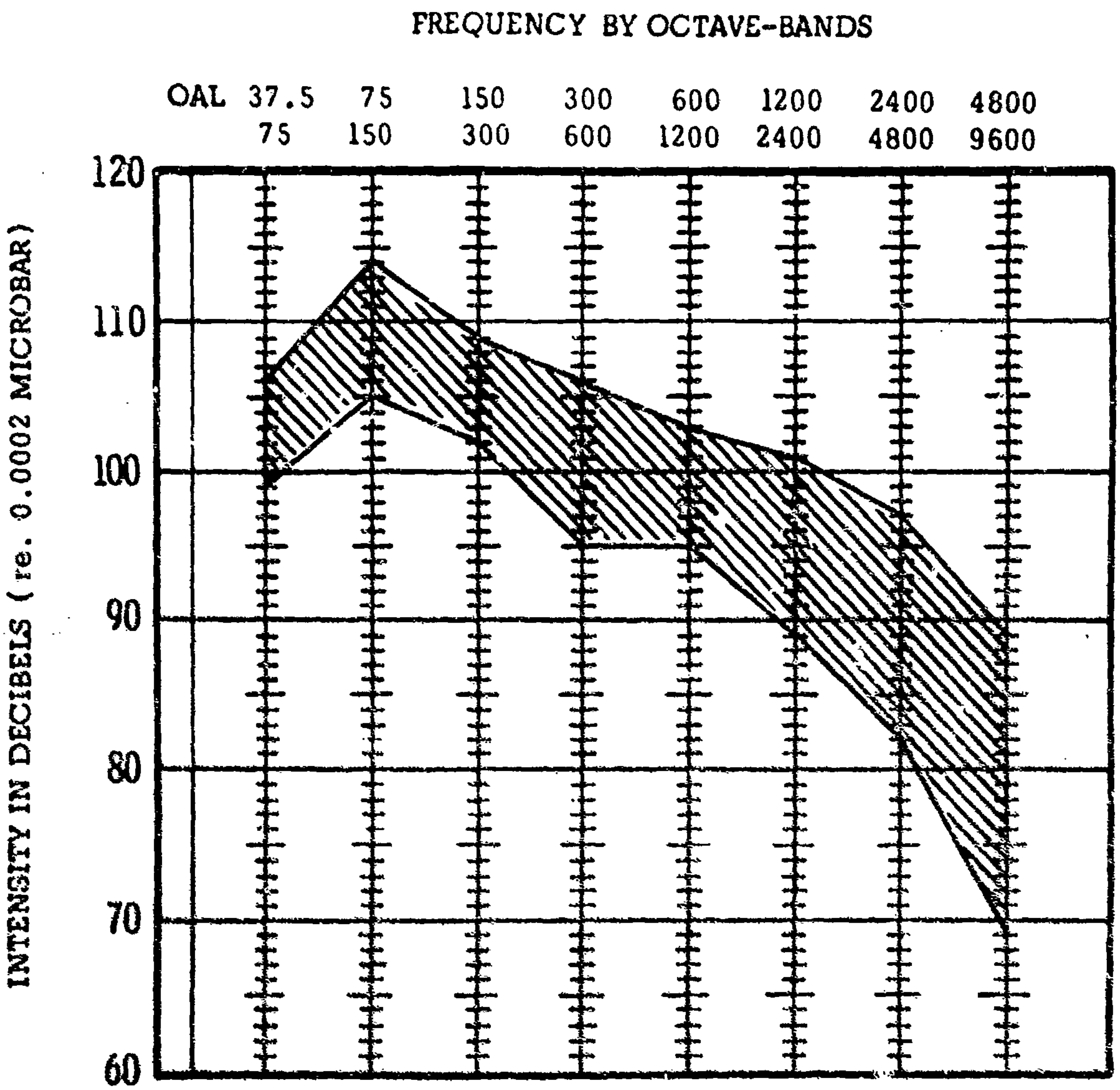

Fig. 27 Internal Noise Envelope of UH-19D Helicopter During Normal Cruise at 500' Altitude, 2400 RPM, 29" MP, 75 Knots IAS

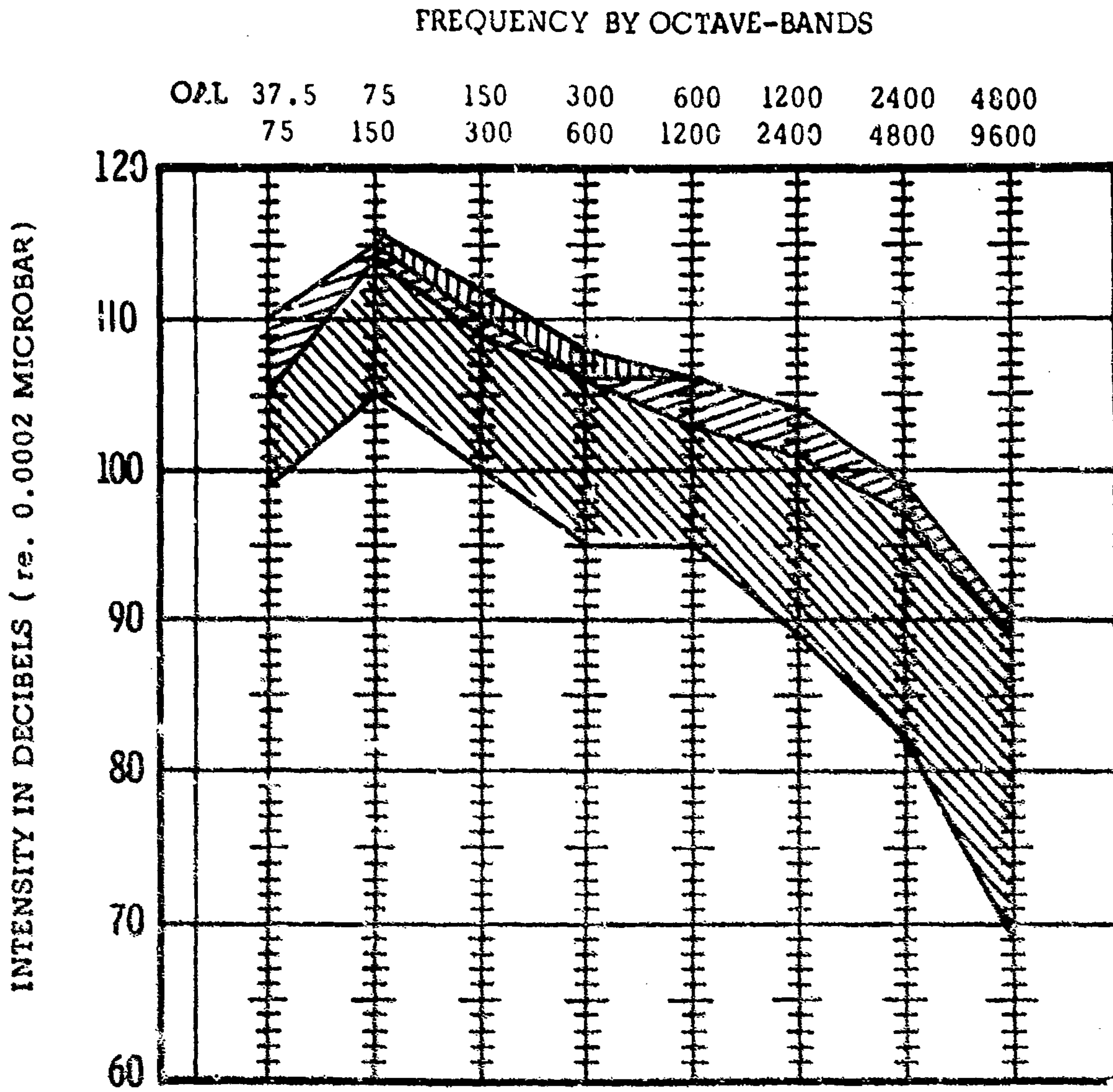

Fig. 28 Internal Noise Envelope of UH-19D Helicopter During a Hover, Normal and Maximum Cruise

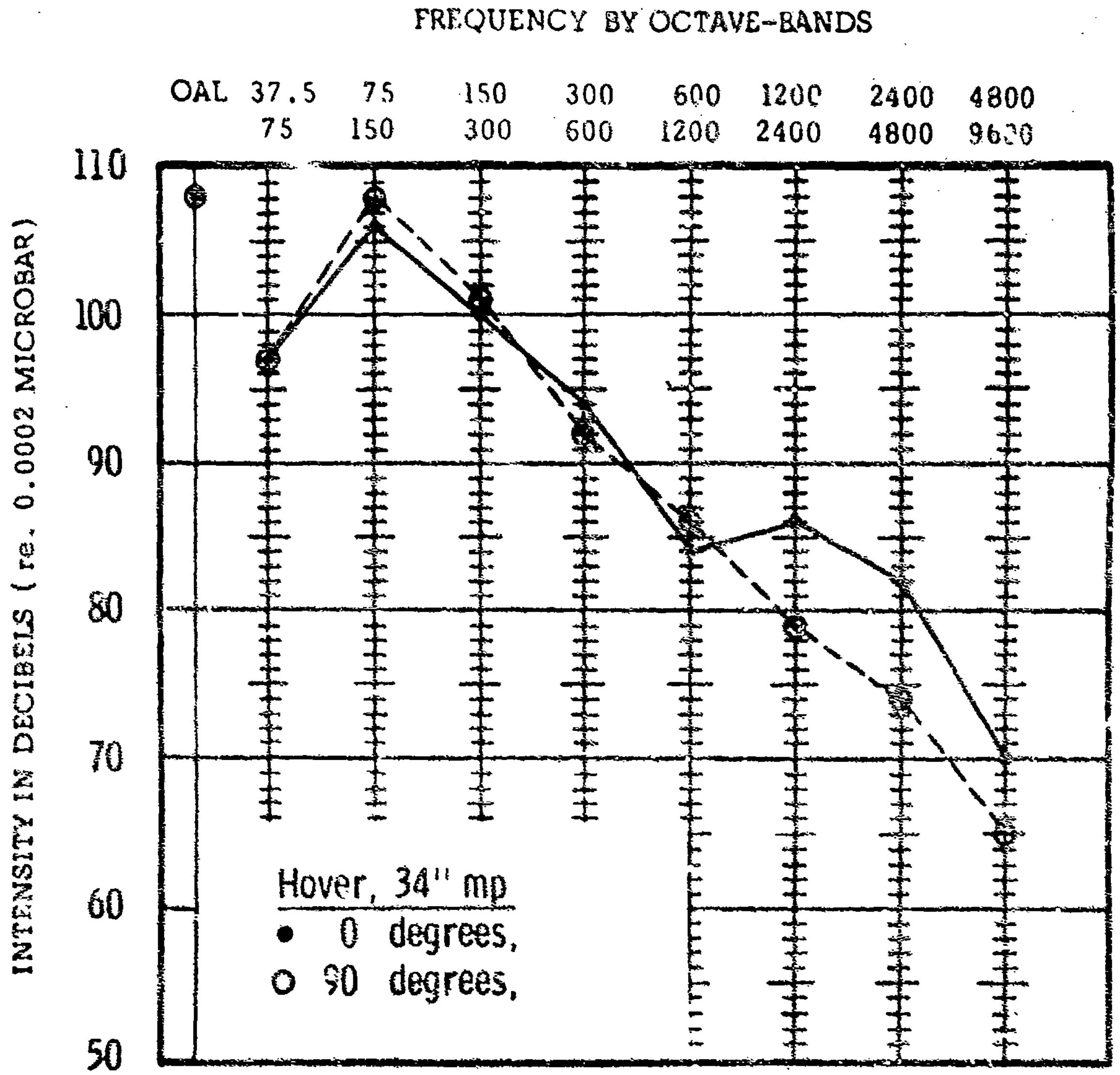

Fig. 29 External Noise of UH-19D Helicopter at a 5' Hover, Measured at 100' Distance, 2400 RPM

CH-21C.

The CH-21C is a tandem-rotor helicopter powered by a single Wright R1820 radial type reciprocating engine which is capable at maximum power of producing approximately 1,425 brake horsepower at 2,700 rpm and a high normal rated power rating of approximately 1,275 brake horsepower at 2,500 rpm. Each rotor system consists of three blades. The rotors have a counterrotating action and the blades slightly overlap in tracking at a position just above the rear of the main cargo area. The total diameter of each rotor system is 44.0 feet.

The shaft of the engine provides direct drive to a gear-distribution unit which is located within the fuselage directly behind the passenger-cargo compartment. The shaft-distribution unit distributes the shaft power to the forward and aft transmission systems without providing gear reduction. A rotor gear reduction of 9.7-to-1 is provided by the transmission units located beneath each rotor shaft; thus the distribution shaft passing overhead in the passenger-cargo area rotates at the same rpm as the main shaft of the engine. For this reason, rather high frequency noise components are associated with the shaft-distribution unit.

Internal Noise: Noise generated within the CH-21C is a mixture of noise elements generated by various sources (Figure 30, page 46). For instance, the pilot's compartment contains a significant amount of noise within the 37.5 through 1200 cps frequency range. As shown in later noise plottings, the noise in the 300 through 1200 cps range is generated primarily by the forward gear-reduction transmission system which is located over the doorway area leading to the pilot compartment. Noise emanating from the rotors is found to be most intense in the 37.5 through 75 cps octave band and tends to be evenly distributed throughout the passenger-cargo area of the helicopter. The low frequency noise generated by the rotors determines the overall levels recorded throughout the helicopter. Noise generated by the high-speed (nonreduced rpm) distribution shaft is increased somewhat in the 2400 through 4800 cps octave band as one moves toward the rear of the passenger-cargo area. This increase is primarily due to the influence of bearing and shaft support components that are located just above the cargo area between the first and second windows (shown in the drawing as the door area). This noise contains high frequency components which are generated by the very high rpm that the torque-distribution shaft rotates (2,500 rpm). Some of the most interesting noise components are contained within the 1200 to 2400 cps range. This noise is generated by the shaft mating and distribution box located above and to the rear of the aft passenger-cargo area. The magnitude of the acoustical energies present within this frequency range increases as one approaches the aft passenger-cargo area near the unit. Even though considerably less intense, the acoustical energy present in the 4800 to 9600 cps octave band also tends to increase in magnitude as one moves toward the far aft part of the passenger-cargo area.

The following noise plottings show the more detailed noise exposures generated within a CH-21C during various flight operations. Figure 31, page 47, demonstrates the influence of rotor and transmission noise on the internal noise environment found near the forward cockpit area. These measurements were completed while the helicopter was operating at a hover. The forward transmission unit is operating to reduce shaft input speed of 2,500 rpm to a rotor shaft speed of 257.7 rpm. To accomplish this, a gear reduction of 9.7-to-1 is utilized, and the noise produced by the gears and shafts within the transmission system (particularly the gear-reduction systems of planetary gears, both pinion and spur type) produce noise levels as indicated in the plottings. At a location directly beneath the transmission unit, the peak higher frequency component produced by the transmission and shaft systems is found to be in the 1200 to 2400 cps octave band. The lower frequency elements of the transmission noise are generated within the cockpit area because the side casing of the transmission is located in such a position that the lower frequency noise components generated by the larger outer bell and reduction gear assembly radiate noise directly within the cockpit. Directly beneath the unit, the noise components generated by the smaller and higher speed planetary gears is noticeable. Also, high frequency noise generated by the high-speed torque-distribution shaft is noticeable near the aft end of the forward transmission system. The lower frequency noise is produced by both the rotors and the main shaft which is mated to the forward rotor. Noise plottings in Figure 32, page 48, illustrate noise measurements taken at a center line position in the front and far aft part of the helicopter during normal cruise. Both noise measurements show the influence of rotor noise which is most evident in the lower frequency ranges and the influence of high-speed gears and shafts which produce distinct higher frequency noise. The noise generated within the pilot compartment contains a lower frequency noise element at 600 to 1200 cps, which is produced by the forward transmission section. Noise measurements taken in the far aft sections of the helicopter demonstrate the presence of a higher frequency noise in the 1200 to 2400 cps octave band. This noise component is generated by the gear-distribution housing located in this area and, since this unit distributes the shaft rpm and does not reduce the shaft speed coming from the engine, the noise component is most pronounced in the higher frequencies.

Noise plottings in Figure 33, page 49, illustrate the differences in noise exposure that exist in the center aisle and to the side of the same station position within a CH-21C. The noise produced in the center of the helicopter during normal cruise is generated primarily by the overhead shaft unit, which is most evident at 600 through 2400 cps. The noise generated at the window location in the same station area demonstrates the dominance of rotor noise, which peaks at 75 through 150 cps, although the presence of shaft noise is still evident in the 1200 to 2400 cps frequency range.

The influence of engine rotor power and airspeed on internal noise is shown in Figure 34, page 50. At the side of the front left window the noise alterations due to engine rotor power and airspeed are quite evident.

Figure 35, page 51, illustrates the noise generated within the far aft sections of the passenger-cargo area when the acoustical blanket located between the engine and the passenger-cargo area is open and closed. Although the over-all noise levels show very little, if any, over-all reduction, the spectrum plottings clearly illustrate a reduction in the magnitude of the acoustical energy present within the higher frequency ranges. Noise in the higher frequencies, especially above 1200 cps, when attenuated by a noise blanket, produces a considerable reduction in subjective irritability and annoyance factors. The most pronounced noise reduction achieved with the noise-reduction blankets utilized in the CH-21C was found above 2400 cps.

<u>External Noise:</u> The external noise of a CH-21C consists primarily of acoustical energy produced by engine exhaust and rotor disturbances. Figure 36, page 52, illustrates results of noise measurements taken at a distance of 50 feet from the helicopter while the engine was operating at 1,500 rpm and 14 inches manifold pressure. The rotors were not operating, thus the noise exposures measured are most representative of engine exhaust noise. The over-all noise levels are similar but the spectrum plottings indicate that the exhaust noise becomes more dominant as one moves toward locations nearer the side of the helicopter. The increased energy in the higher frequency range is due to the presence of higher frequency harmonics generated by the exhaust of the engine.

The following noise measurements were made at a distance of 100 feet while the helicopter was hovering. During a hover, the engines were operating at 2,500 rpm and the rotors at approximately 260 rpm. The noise measurements depicted on the graphs were taken at similar locations on the right and left sides of the CH-21C. Figure 37, page 53, illustrates noise generated directly to the front and rear of the helicopter. These measurements clearly demonstrate the influence of blade loadings as well as exhaust noise. Plottings of noise measurements taken at 30 degrees from the right and left sides of the helicopter demonstrate an almost equal noise distribution. Likewise, the plottings in Figure 38, page 54, illustrate a relatively equal noise distribution at positions of 60 degrees on the right and left sides of the helicopter.

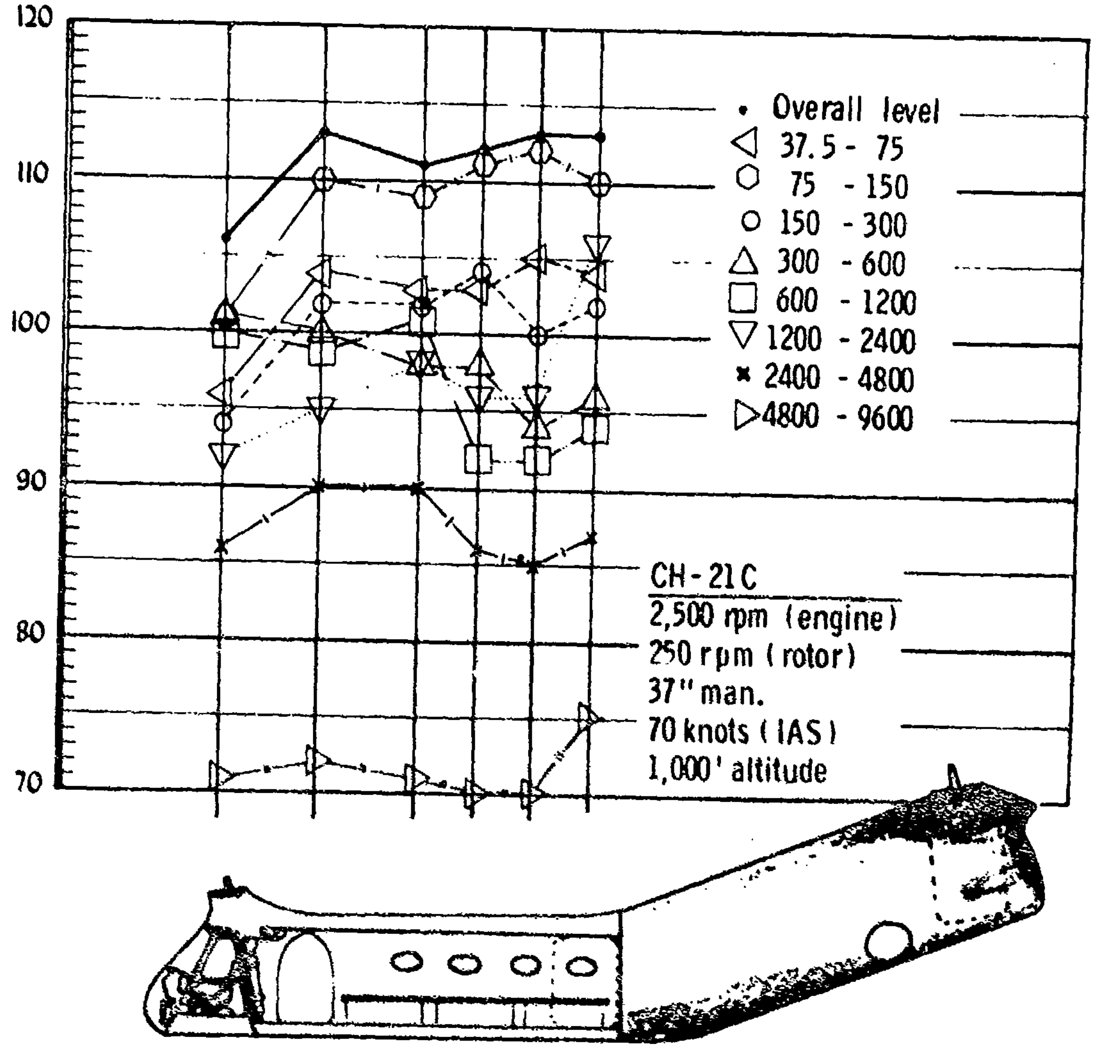

Fig. 30 Internal Noise of CH-21C Helicopter During Normal Cruise at 1000' Altitude, 2500 RPM, 37" MP, 70 Knots IAS

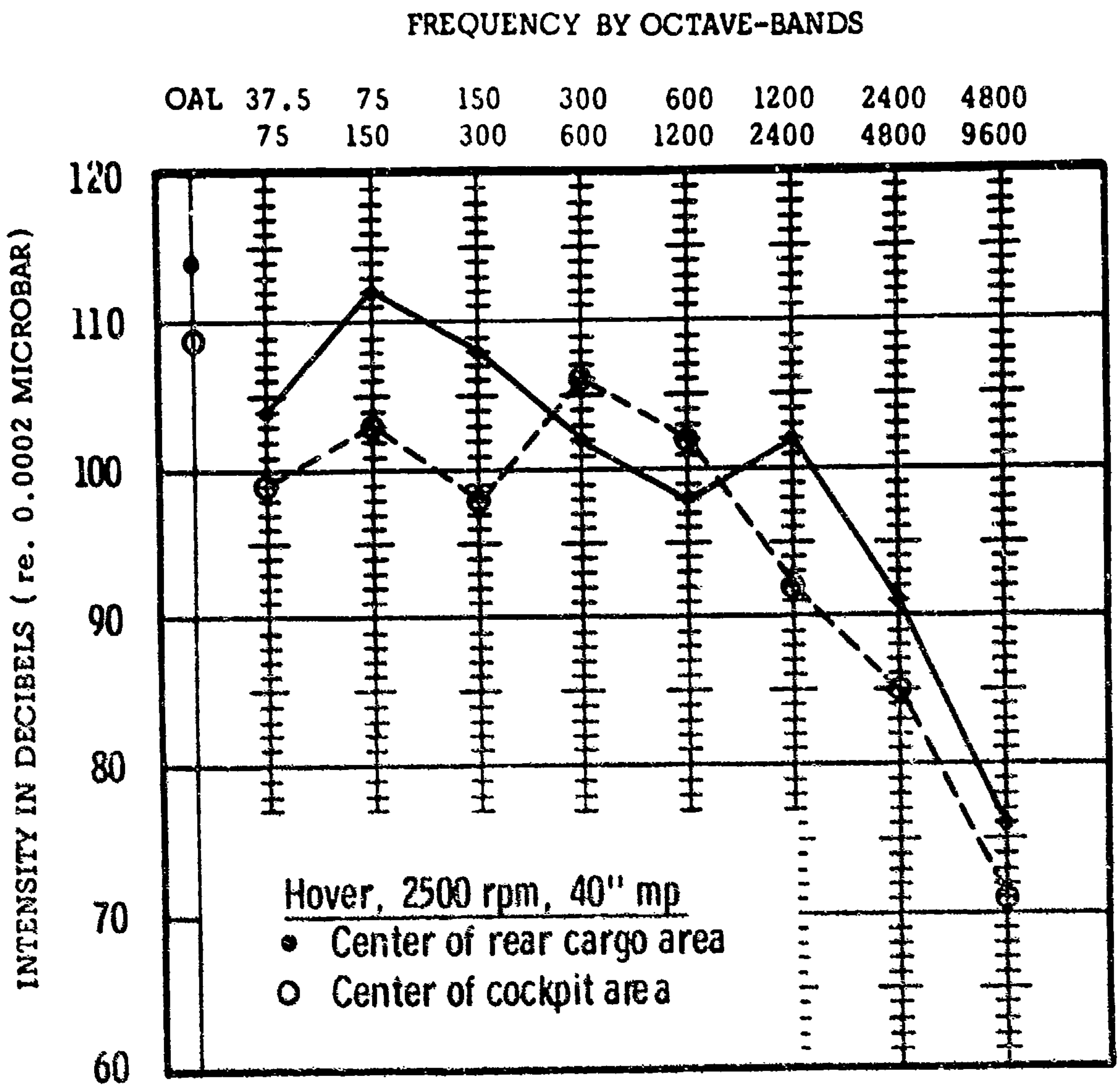

Fig. 31 Internal Noise of CH-21C Helicopter During a Hover

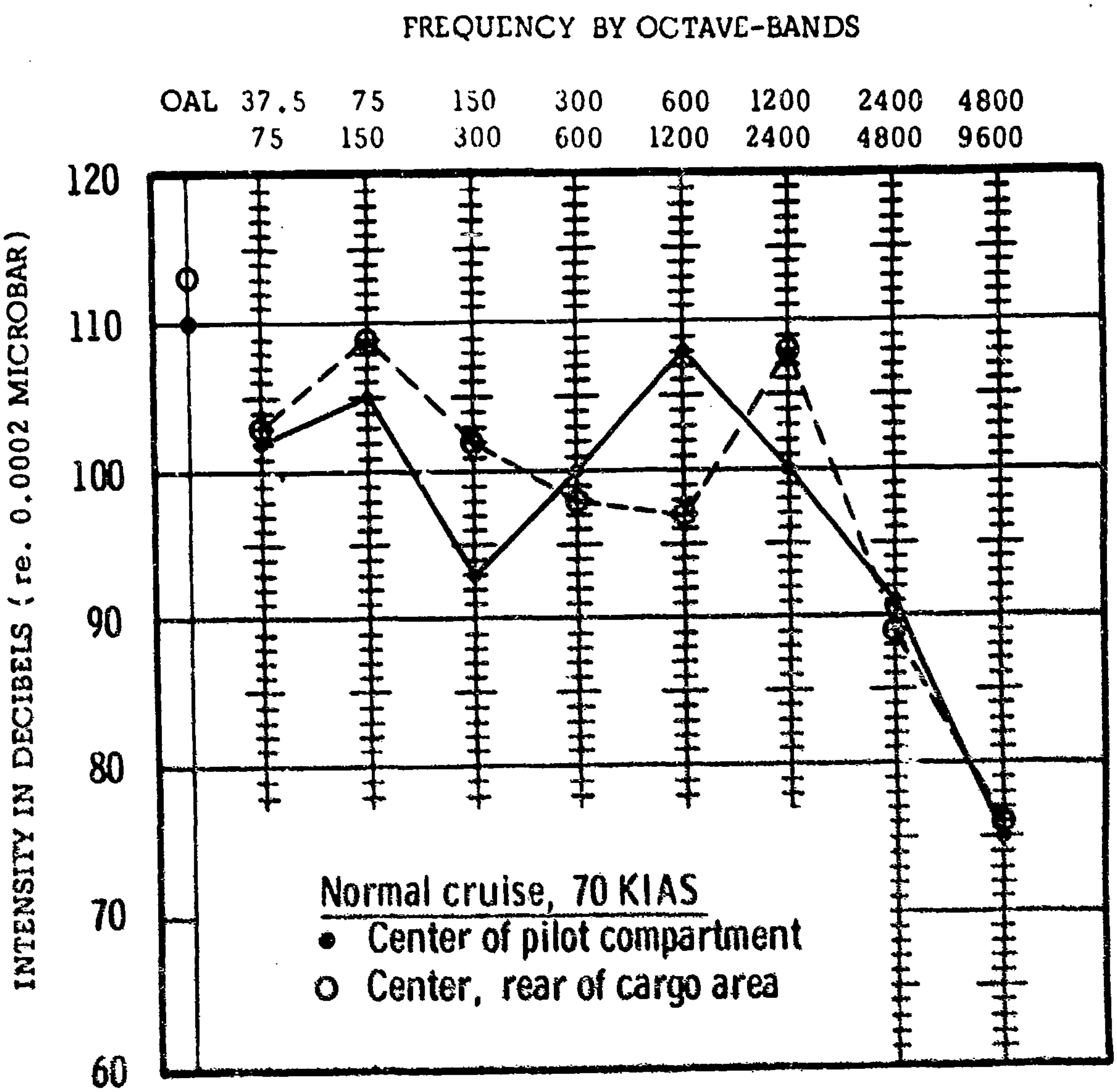

Fig. 32 Internal Noise of CH-21C Helicopter During Normal Cruise at 1000' Altitude, 2500 RPM, 37" MP

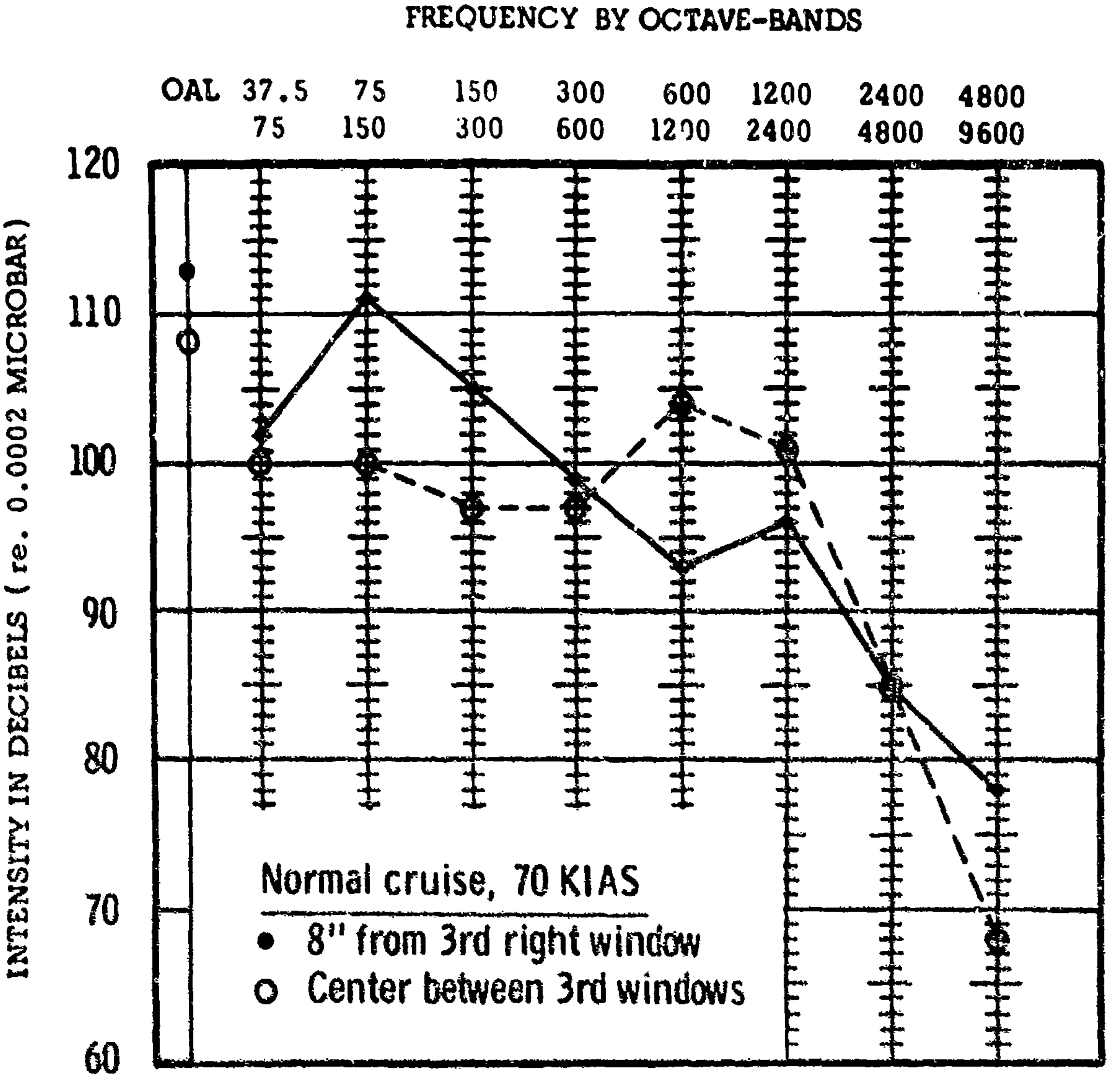

Fig. 33 Internal Noise of CH-21C Helicopter During Normal Cruise at 1000' Altitude, 2500 RPM, 37" MP

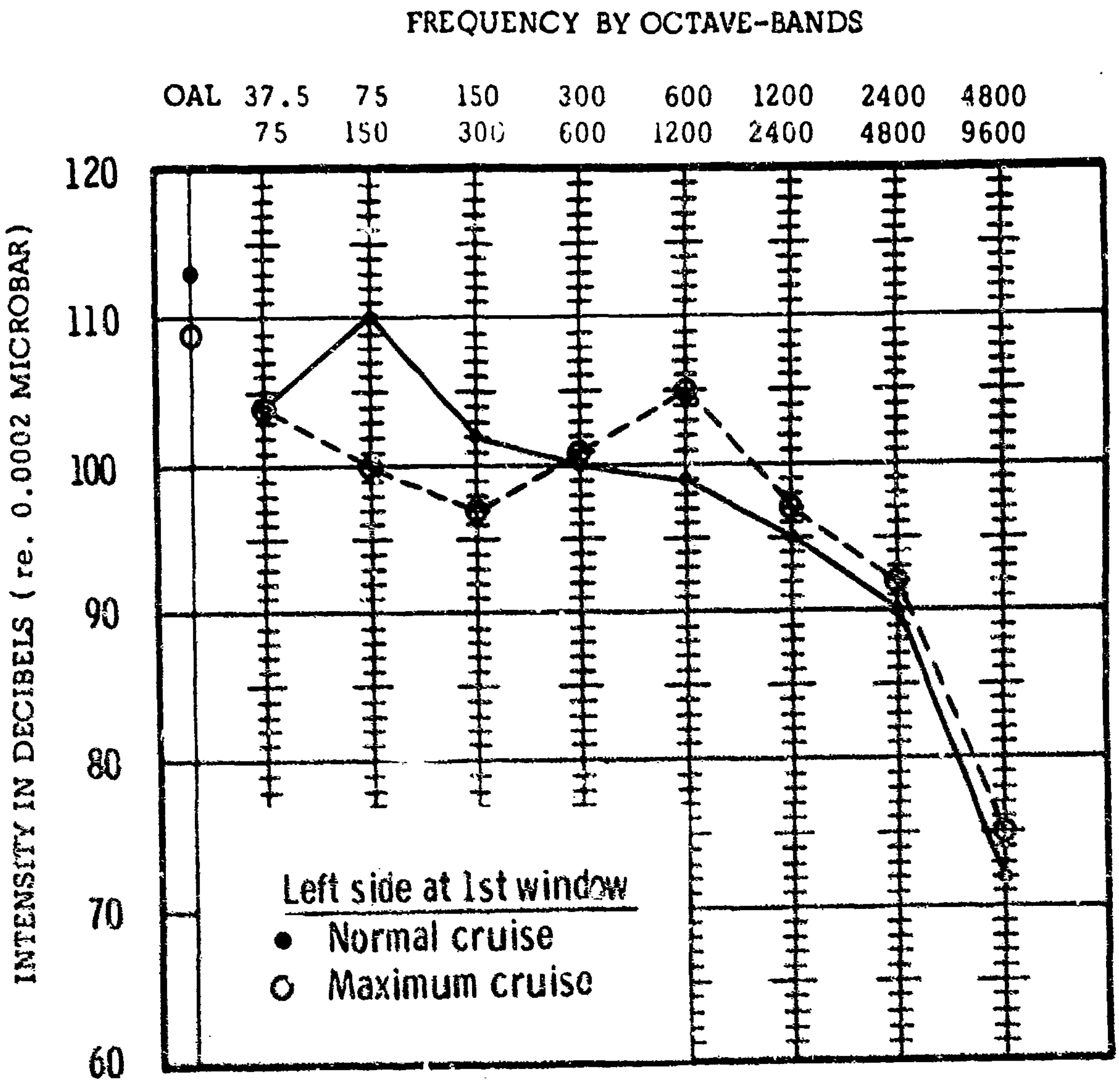

Fig. 34 Internal Noise of CH-21C Helicopter During Normal and Maximum Cruise at 1000' Altitude

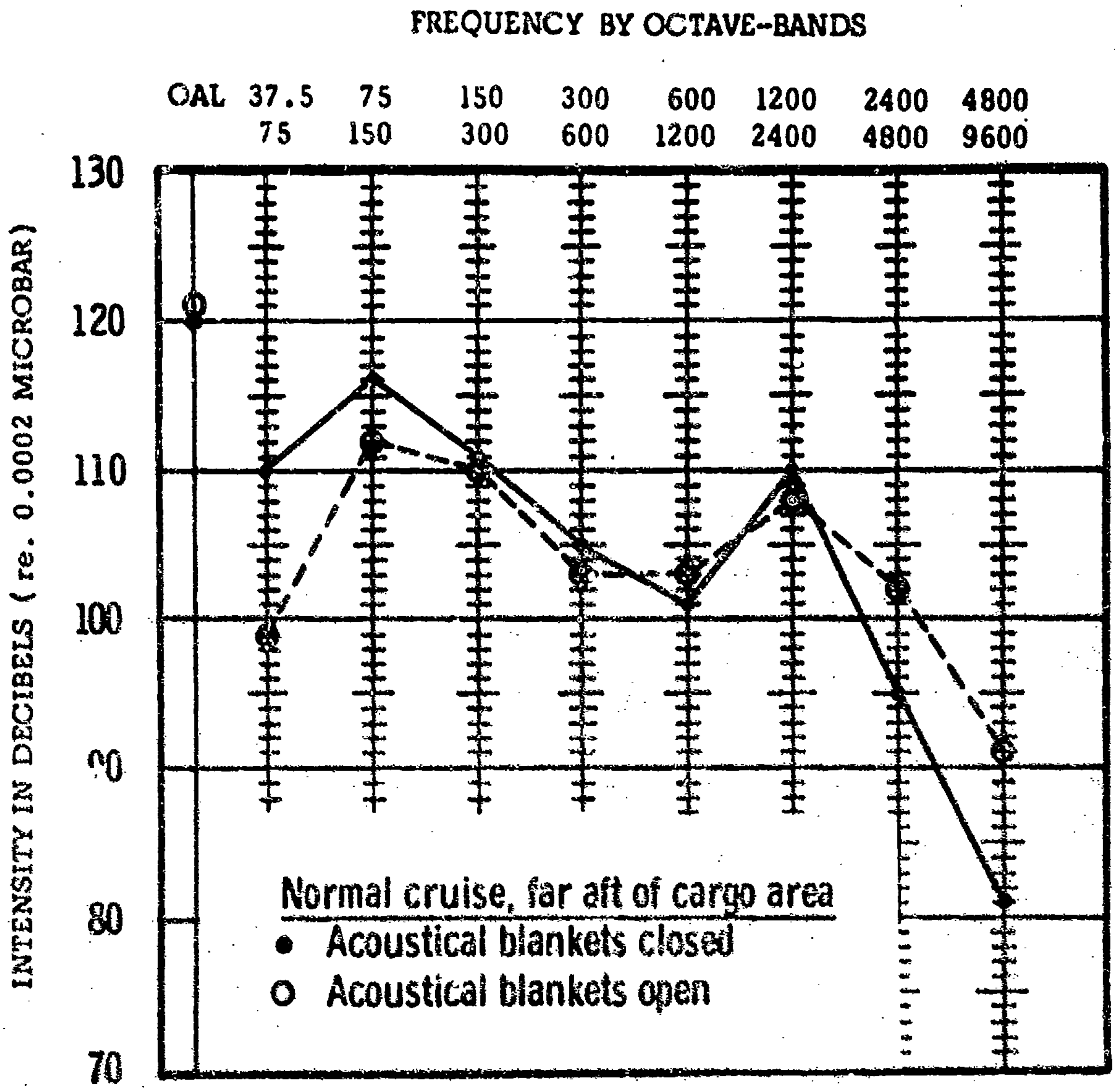

Fig. 35 Internal Noise of CH-21C Helicopter During Normal Cruise, Blankets Open and Closed

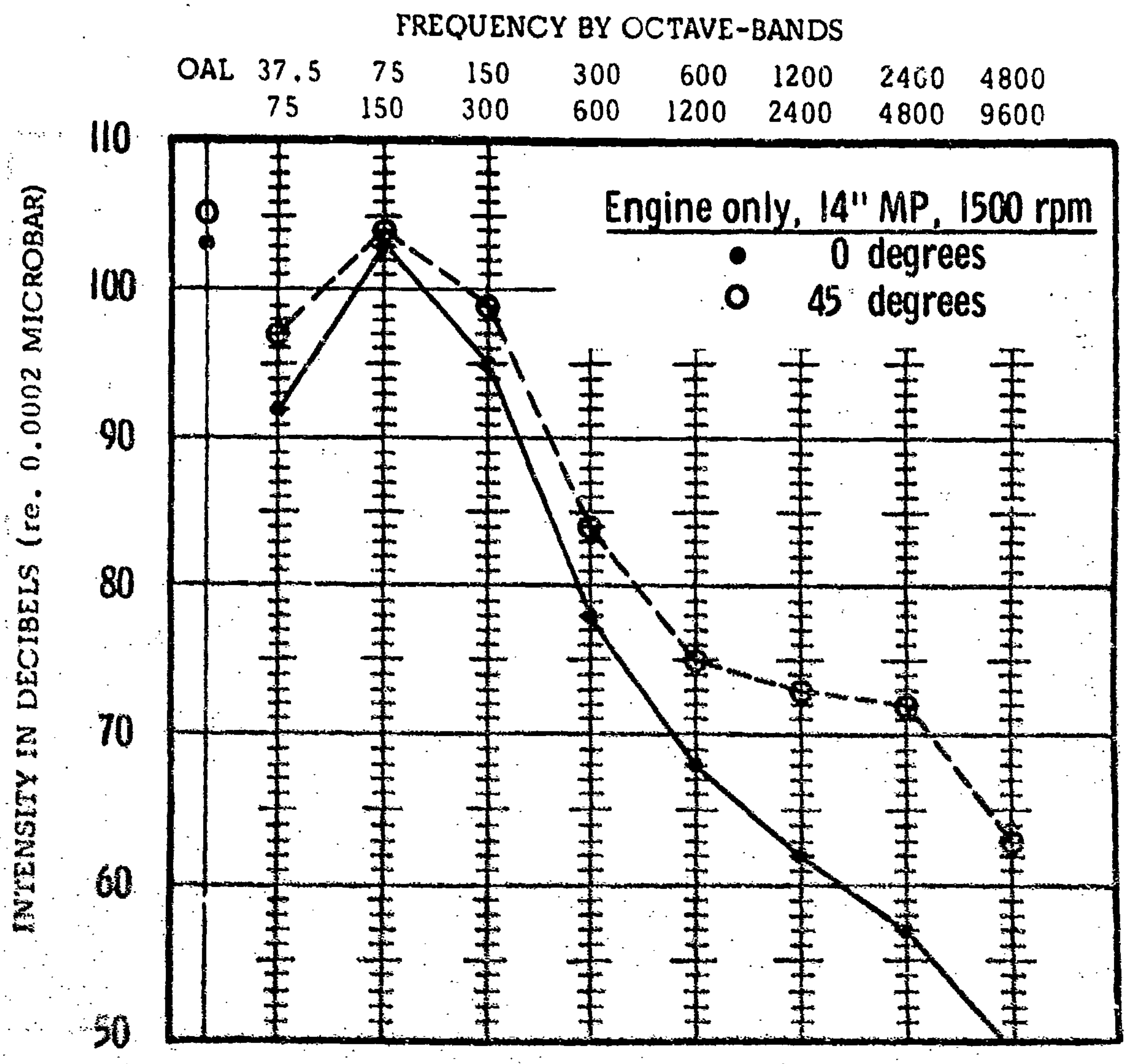

Fig. 36 External Noise of CH-21C Helicopter During Ground Operations, Measured at 50' Distance

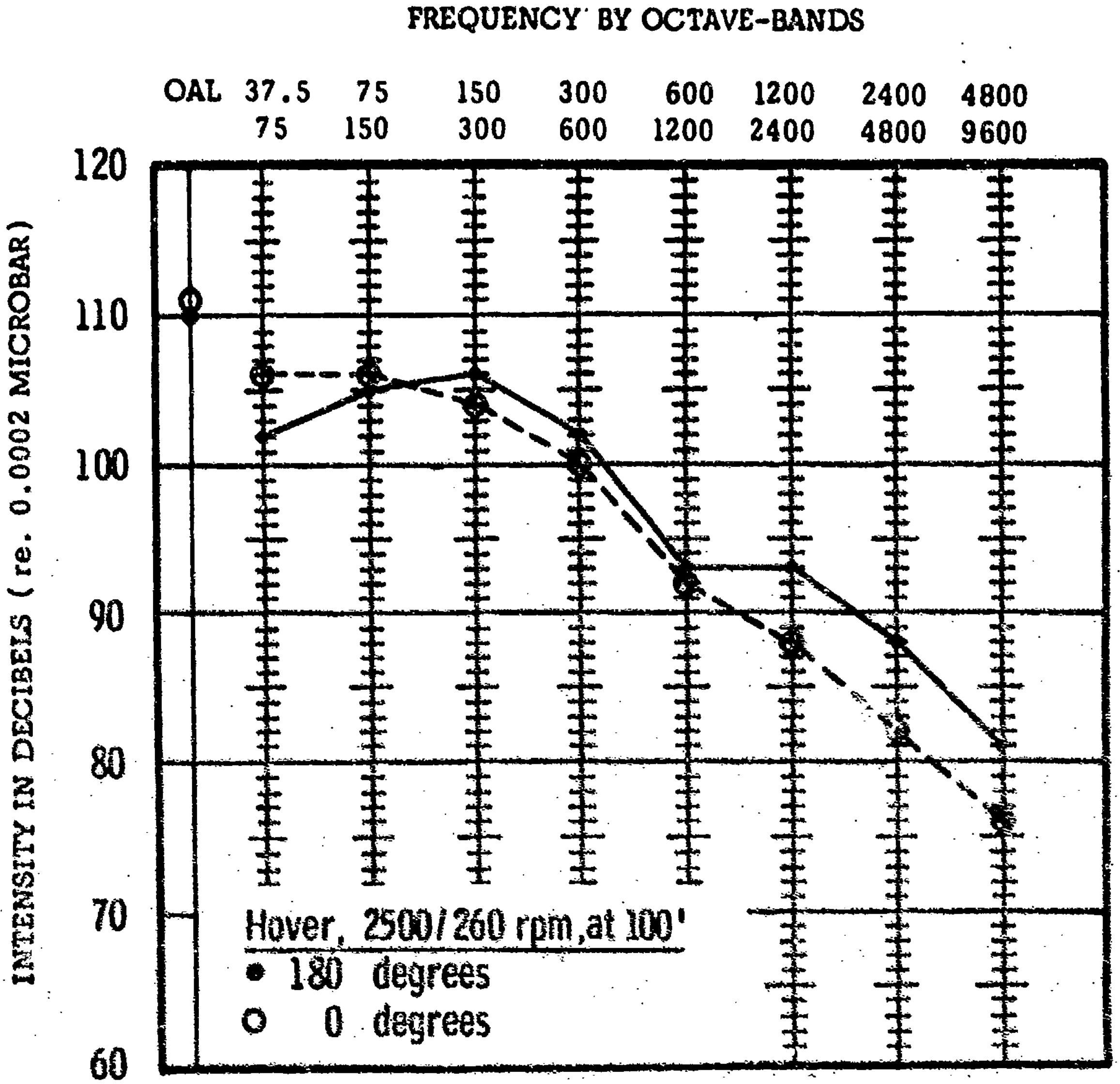

Fig. 37 External Noise of CH-21C Helicopter During a Hover, Measured at 100' Distance, 0 and 180 Degrees

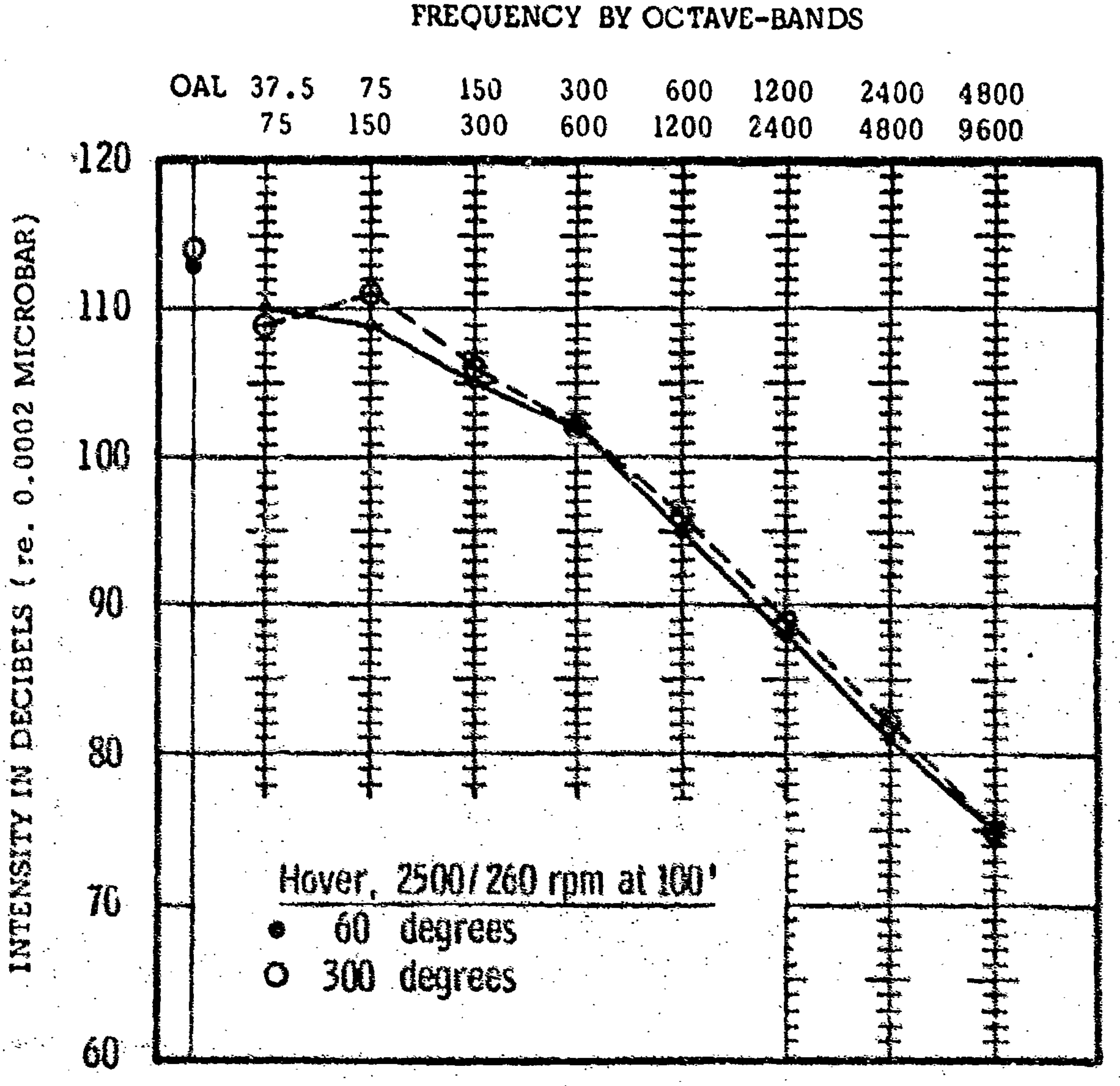

Fig. 38 External Noise of CH-21C Helicopter During a Hover, Measured at 100' Distance, 60 and 300 Degrees

OH-23D.

The OH-23D is a small two- or three-place helicopter with a single two-blade main rotor which has a diameter of 35'5" and a two-blade antitorque rotor having a diameter of 5'8". The OH-23D is powered by a single Lycoming VO-435 reciprocating engine which produces approximately 245 brake horsepower at 3,200 rpm during operation at normal rated power.

The major noise producing mechanisms, like similar single-rotor helicopters powered by small reciprocating engines, consist of noise components generated by the main rotor, the antitorque rotor, and the engine exhaust.

Internal Noise: Figure 39, page 56, illustrates noise measurements completed at the left ear level of the instructor pilot located in the left seat position. These measurements were taken while the aircraft was operating at normal and high cruise. At normal cruise the aircraft was flying at 55 knots (IAS), and at high cruise the aircraft's speed was increased to 80 knots (IAS). As shown by the noise plottings at these two power operations, the internal noise levels are essentially the same. In Figure 40, page 57, noise plottings were made at the same locations, except during these measurements the levels are indicative of ground level versus hover operation. During ground run-up the presence of engine exhaust noise is quite intense, peaking at 75 to 150 cps. During a hover the exhaust noise is not as dominant, and the spectrum of the noise exposures encountered during this operation is basically flat, peaking slightly at 75 through 600 cps. The noise levels recorded during a hover are produced primarily by the main rotors. Although the over-all levels recorded during a hover are less than those recorded during ground operations, the subjective evaluation of the noise is somewhat higher due to the presence of a greater amount of acoustical energy in the frequency ranges above 300 cps.

External Noise: Noise generated during ground operations is depicted in noise plottings of Figure 41, page 58. These measurements were taken at a distance of 50 feet while the helicopter maintained a three foot hover. The engine was operating at 3,200 rpm and the rotor was rotating at 370 rpm. Noise measured at three locations (0, 90, and 180 degrees) present a good illustration of the different noise levels produced by various noise generating mechanisms. For instance, at 0 degrees (directly in front of the helicopter) the most evident noise is produced by disturbances created by the blades of the main rotor. At a position of 90 degrees from the front of the aircraft (directly to the side of the helicopter) the rotors contribute to the noise; but the presence of noise emanating from the exhaust of the engine and the tail rotor is more pronounced than at locations in front of the helicopter. At a position of 180 degrees some of the noise generated by the tail rotor is evident in the frequency range above 1200 cps.

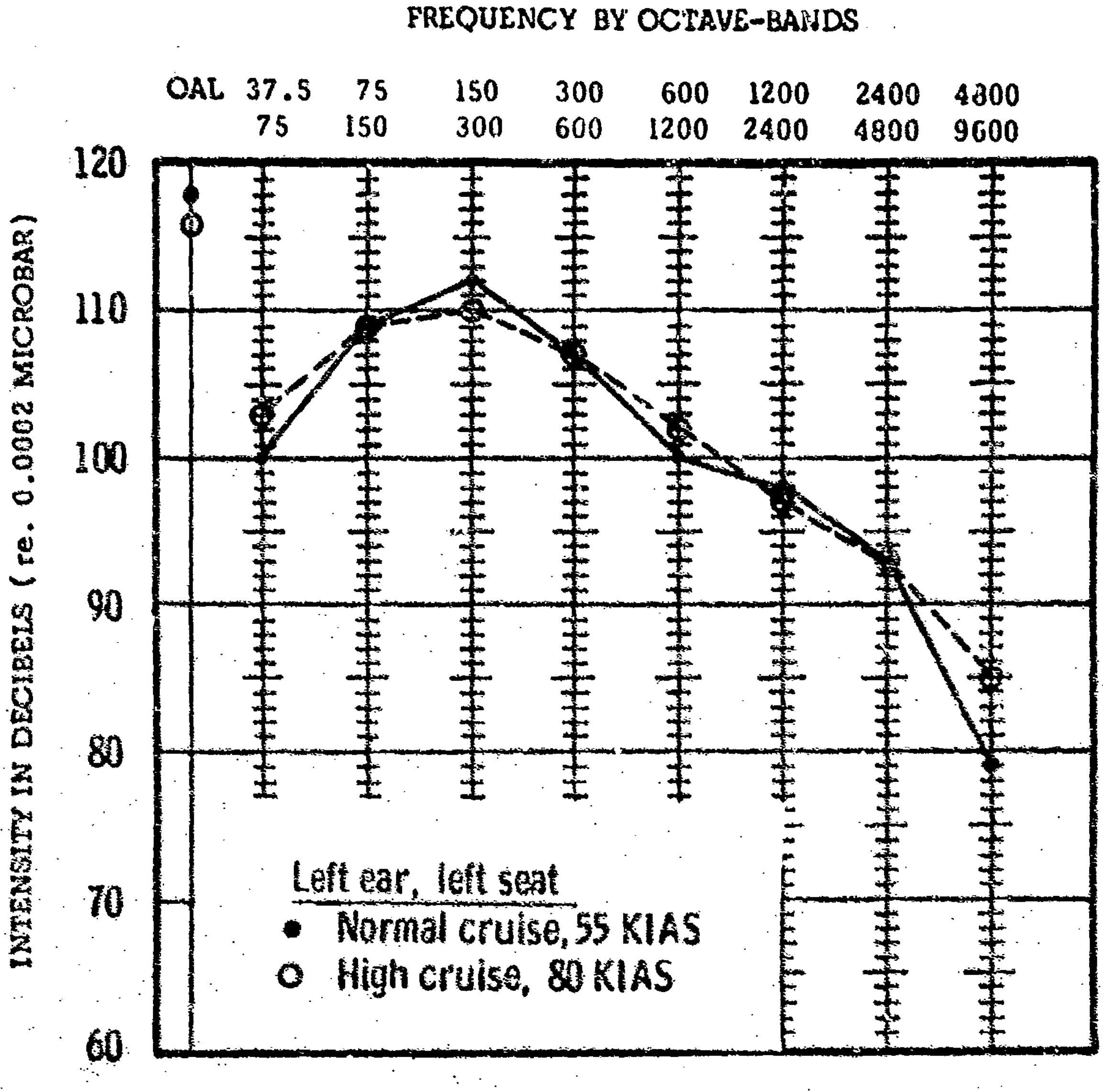

Fig. 39 Internal Noise of OH-23D Helicopter During Normal and Maximum Cruise

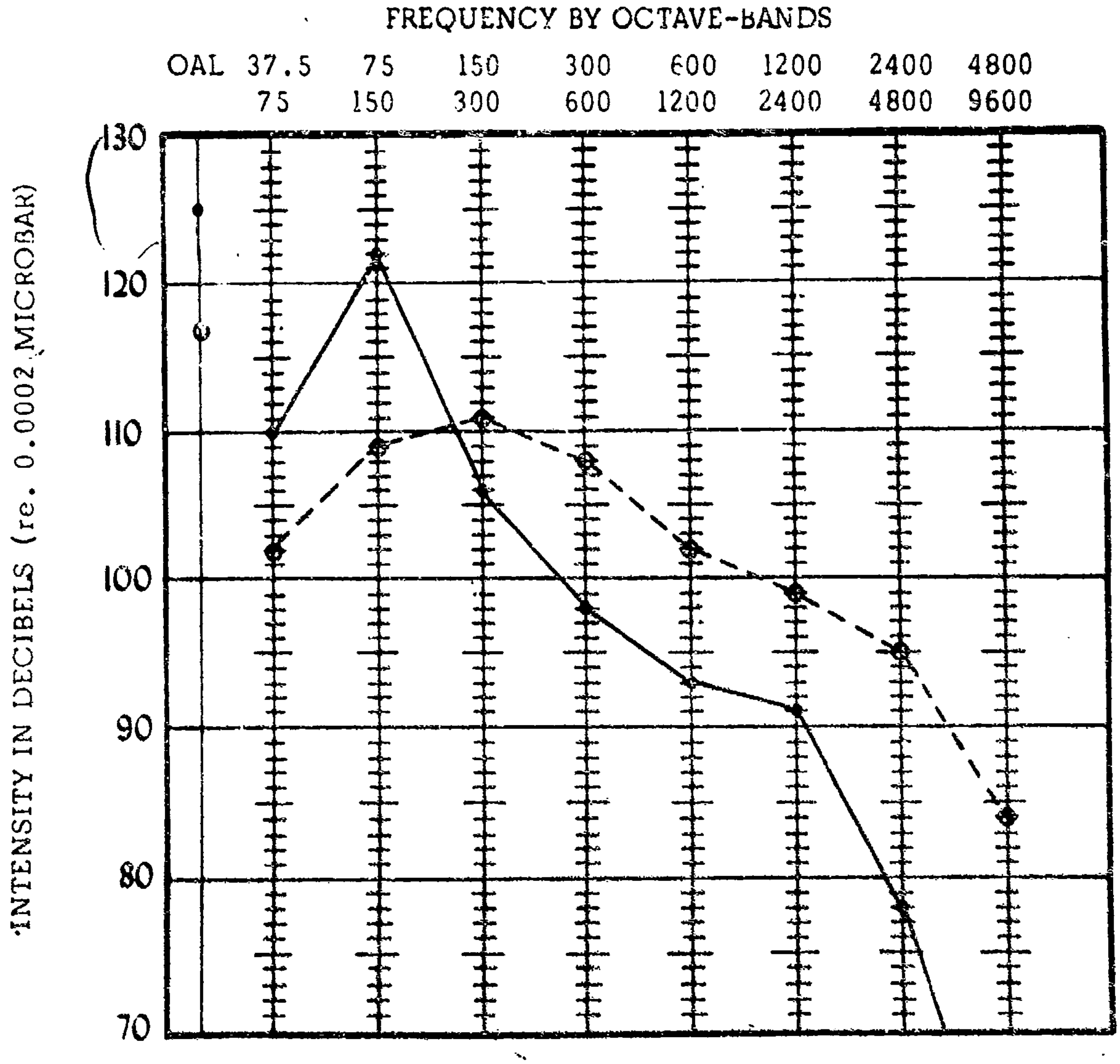

Fig. 40 Internal Noise of OH-23D Helicopter During Ground Operations and a Hover

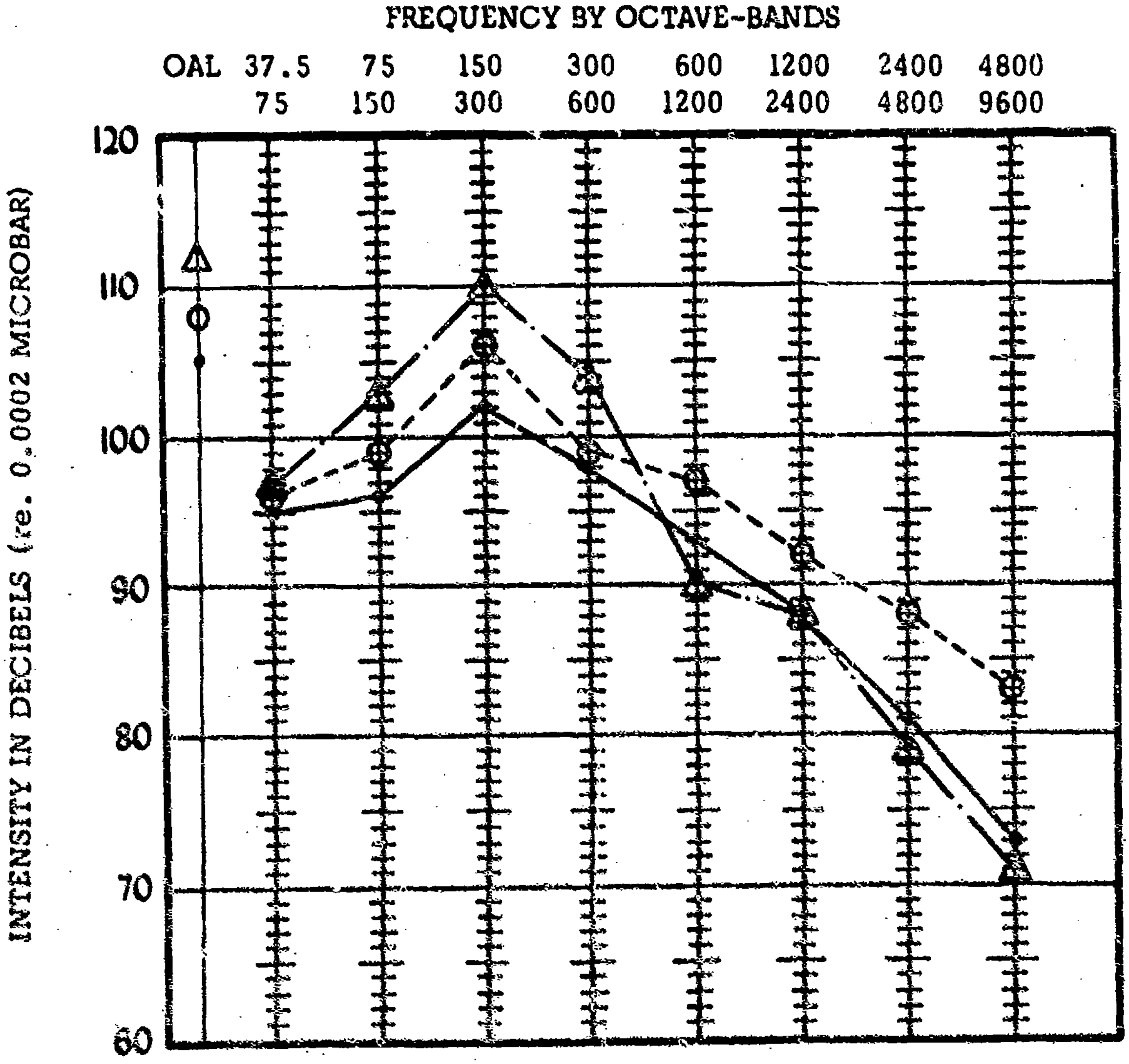

Fig. 41 External Noise of OH-23D Helicopter During a 3' Hover, Measured at 50'; 0, 90, and 180 Degrees

CH-34C.

The CH-34C is a single-engine helicopter with a single four-blade main rotor having a diameter of 56'0" and a four-blade antitorque tail rotor having a diameter of 9'6". The aircraft is powered by a Wright R1820 radial type reciprocating engine which produces approximately 1,400 brake horsepower at 2,700 rpm at maximum rated power and produces about 1,275 brake horsepower at 2,500 rpm for METO (maximum except take-off) power.

The major noise producing elements of the CH-34C are similar to that of the UH-19D. However, the CH-34C achieves a little more reduction of the acoustical energies generated by the main and antitorque rotors because the addition to the number of blades in the rotor and antitorque systems results in less intense rotor and antitorque noise. The engine is mounted in the nose of the helicopter directly beneath the pilot compartment and in front of the passenger-cargo area. The shaft of the engine is inclined upward at an angle of about 35 degrees from the horizontal. The torque-distribution shaft from the engine is located between the pilots and is mated to the main transmission unit directly behind the pilot compartment and above the passenger-cargo compartment. The engine exhaust ports through a single opening located on the left lower section of the clamshell doors.

Internal Noise: The internal noise exposures are directly influenced by the acoustical energies generated by the engine exhaust, the torque-distribution shaft located between the pilots, the main transmission, and the main rotors. Figure 42, page 61, illustrates the noise generated within the pilot compartment at the right ear level of the pilot on the right side. These noise levels were recorded while the helicopter was operating at normal cruise (80 knots IAS). The engine was operating at 2,450 rpm and the main rotor at 218 rpm. Noise levels measured at the pilot position are composed of noise elements emanating from the main rotor, the torque shaft passing from the engine shaft to the transmission unit, and the main transmission unit. Figure 43, page 62, illustrates the similarity of noise exposure produced at the forward section of the passenger-cargo compartment during normal and high cruise. At normal cruise the engines were operating at 2,450 rpm with 34 inches of manifold pressure and the rotor was rotating at 218 rpm. During normal cruise the helicopter was flying at 80 knots (IAS). At high cruise the engine was operating at 2,500 rpm with 38 inches of manifold pressure and the rotor was rotating at 221 rpm. During high cruise the helicopter was flying at 95 knots (IAS). The noise plottings shown in Figure 44, page 63, depict results of noise measurements completed in the aft section of the passenger-cargo area during the same flight conditions. During normal cruise the main rotor had a blade velocity of 639.2 feet per second (0.572 Mach) and at high cruise the speed of the rotor tips increased to approximately 648.0 feet per second (0.580 Mach). It is interesting to note that noise generated by the aerodynamic

pressure disturbances of the main rotor blades is most evident at locations within the aft section of the helicopter. The noise produced by this type of disturbance is distributed primarily in the lower frequency ranges.

External Noise: The rotors, engine exhaust, and antitorque rotors produce the most significant noise levels measured near the helicopter. Since the CH-34C has a single exhaust port which is located on the left side of the helicopter, noise measurements were completed at locations on the left side. Noise measurements completed at 100 foot distance are shown in Figure 45, page 64. Noise emanating from the main rotor dominates the acoustical energies produced by the helicopter during both operations. However, the noise generated by the exhaust and antitorque rotor systems is quite evident during ground operations.

Noise plottings shown in Figure 46, page 65, demonstrate the influence of exhaust disturbances on the near-field noise generated near a CH-34C. During these measurements the helicopter was hovering with the engine at 2,500 rpm, 37 inches of manifold pressure, and 220 rotor rpm. The noise exposures as specified were completed at a distance of 100 feet. The noise exposure on the left side of the helicopter was significantly more intense than at similar locations on the right side of the helicopter due to the influence of exhaust noise. Exhaust noise is evident in the frequency ranges below 600 cps. The slight increase in the acoustical energies above 600 cps is probably due to the noise generated by the antitorque rotor system.

In Figure 47, page 66, the dual influence of exhaust and antitorque rotor noise becomes even more evident. The noise levels reported here are characteristic of noises generated at locations 60 degrees from the right and left sides of the helicopter. The noise plottings at these two similar locations demonstrate the influence of rotor, exhaust, and antitorque noise components on the total noise produced by a CH-34C. The exhaust noise is most intense at locations to the left side of the helicopter because the single exhaust port is located on the left side. Noise emanating from the antitorque rotor system is also most pronounced at positions on the left side of the helicopter because the antitorque rotor is located on the left side of the tail fairing.

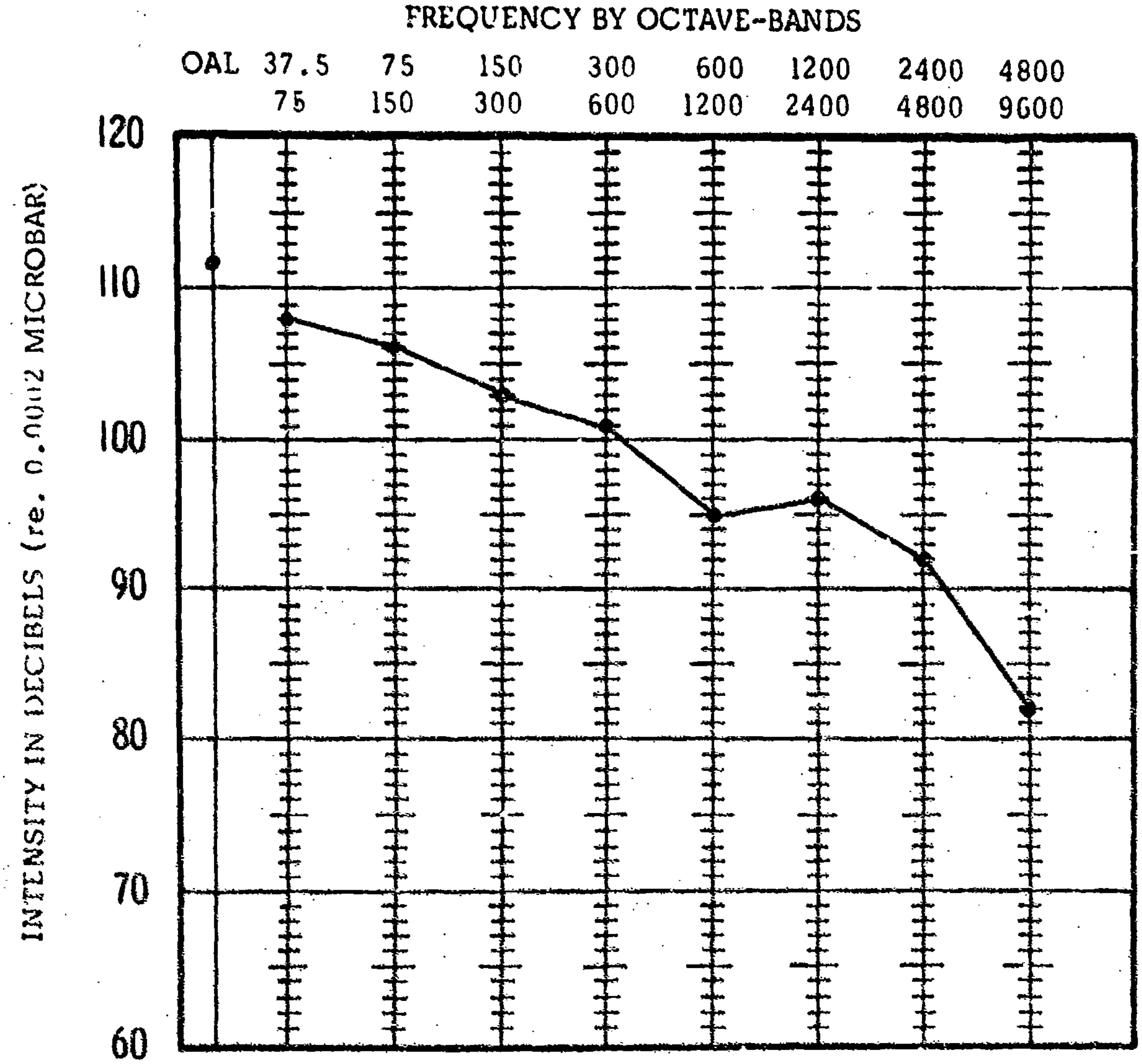

Fig. 42 Internal Noise of CH-34C Helicopter During Normal Cruise, 2450 RPM, 80 Knots IAS

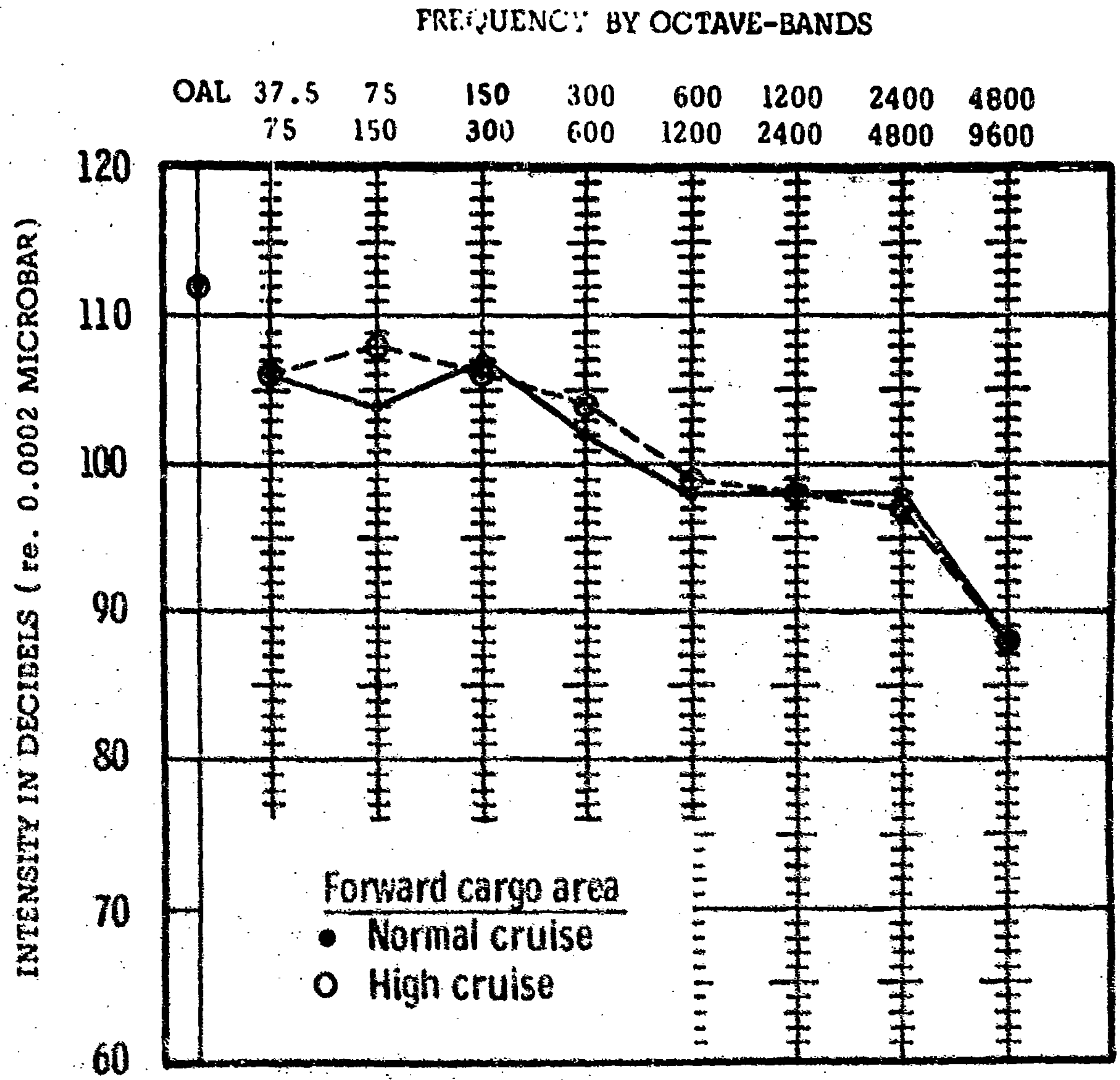

Fig. 43 Internal Noise of CH-34C Helicopter During Normal and Maximum Cruise, Forward Cargo Area

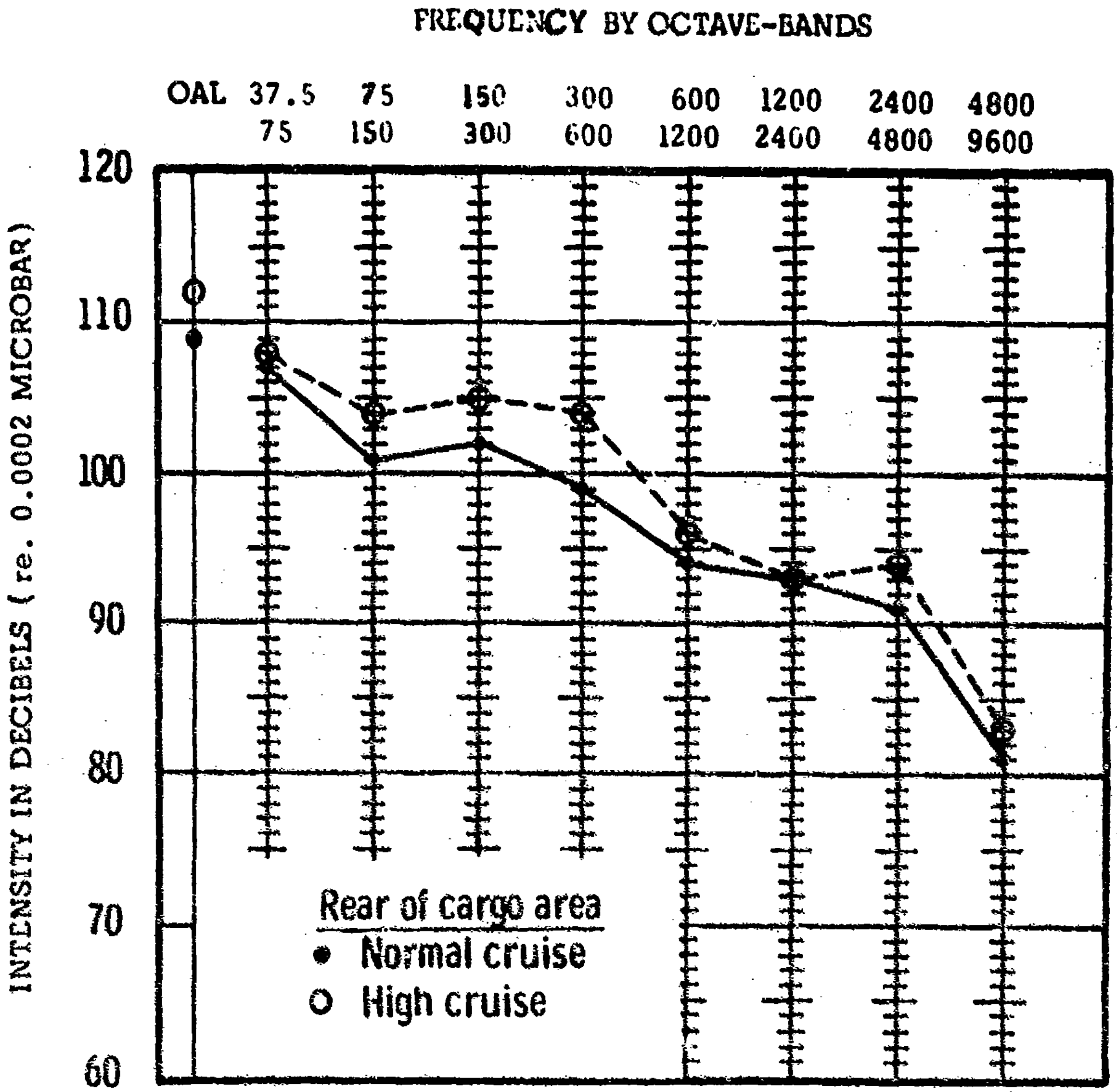

Fig. 44 Internal Noise of CH-34C Helicopter During Normal and Maximum Cruise, Aft Cargo Area

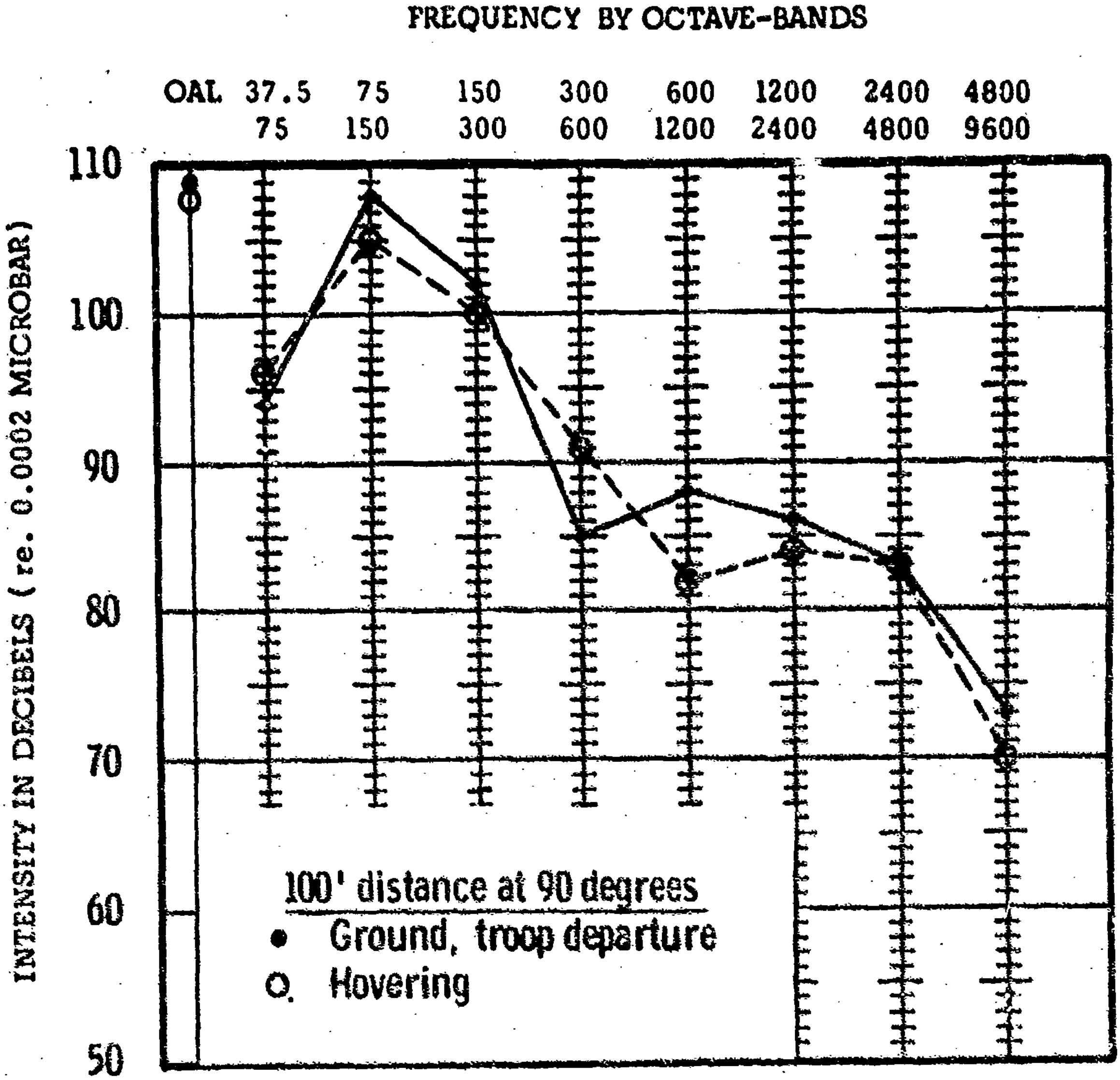

Fig. 45 External Noise of CH-34C Helicopter During Ground Operations and a Hover

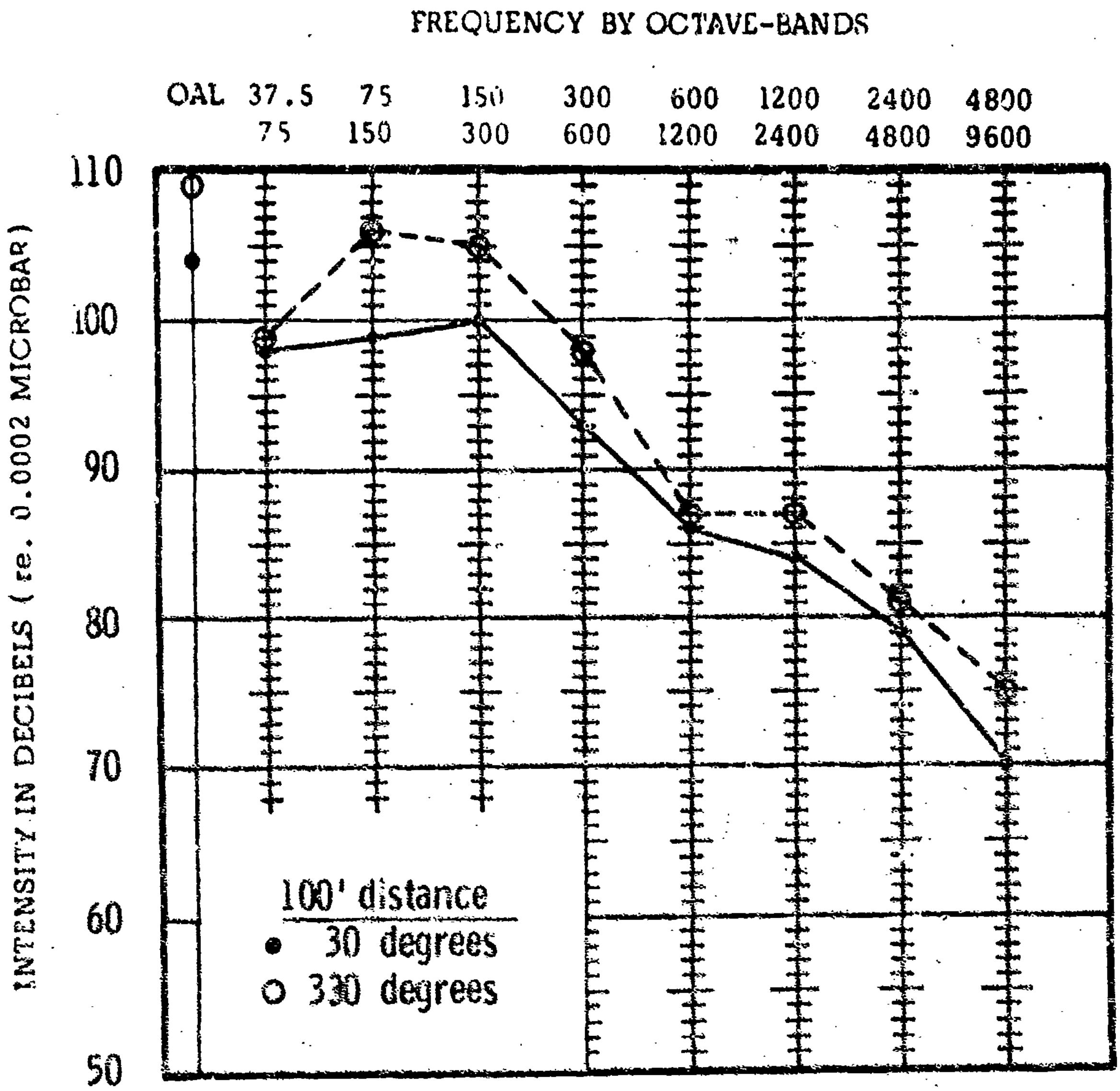

Fig. 46 External Noise of CH-34C Helicopter During a Hover

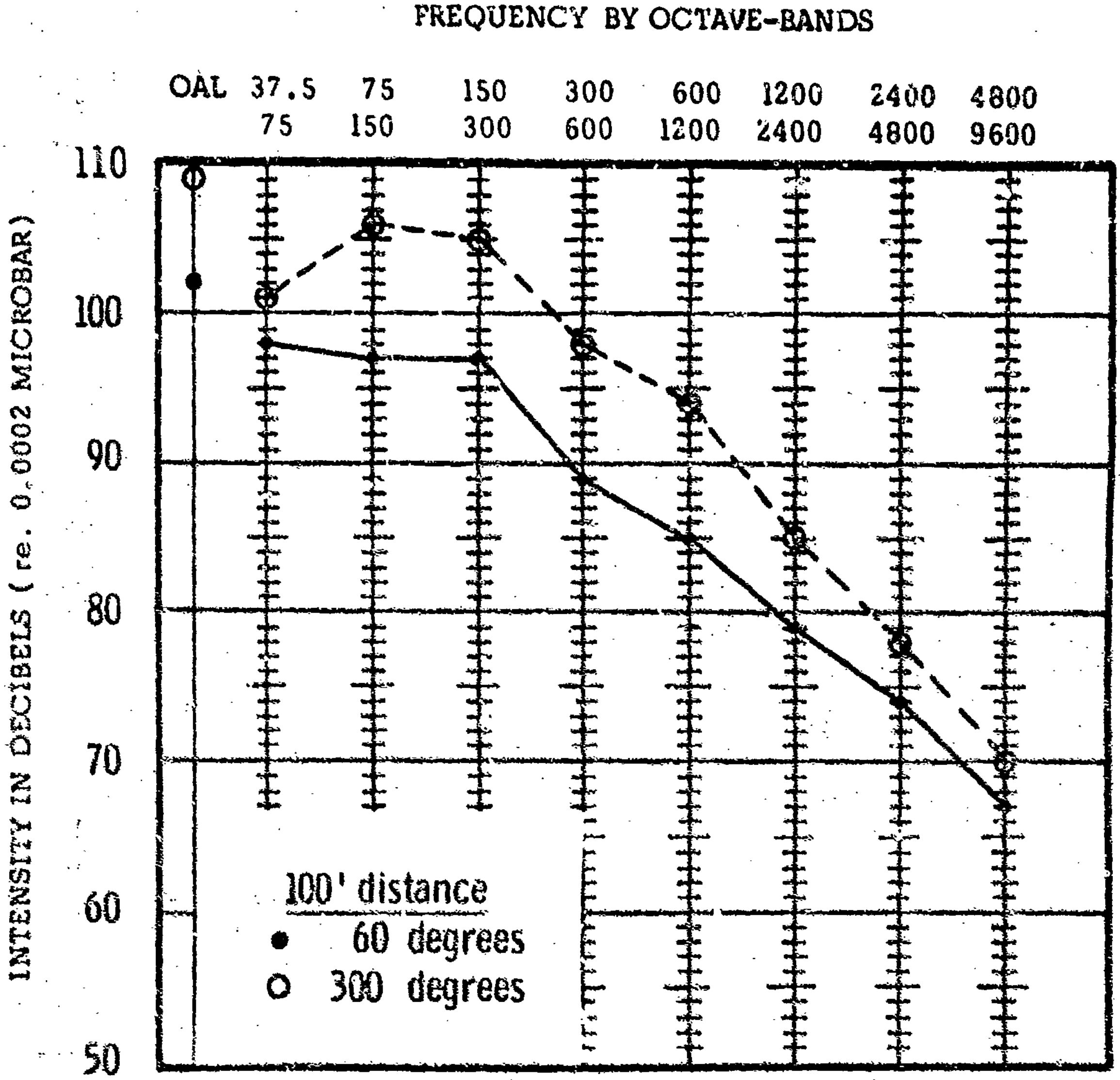

Fig. 47 External Noise of CH-34C Helicopter During a Hover

CH-37B.

The CH-37B is a medium transport helicopter powered by dual engines that drive a single main rotor and an antitorque rotor system. The CH-37B is fitted with two Pratt and Whitney R2800 radial type reciprocating engines that produce approximately 2,100 brake horsepower at 2,700 rpm during maximum power with a capability of providing about 1,725 brake horsepower at 2,600 rpm at METO power.

Each engine is mounted in a nacelle that is located on the outer edges of two short pylon type wings. The shaft of each engine transfers shaft torque power to a centrally located single transmission and gear-distribution unit which is directly beneath the main rotor fairing. The main rotor has five blades and a rotating diameter of 72'0". The tail rotor has four blades and a rotating diameter of 15'0".

Noise levels existing within the helicopter are directly influenced by noise components generated by the transmission, the engine exhaust, and the main rotor. Noise levels generated externally are created primarily by acoustical disturbances generated by the main rotor, the antitorque rotor, and the engine exhaust (especially at locations aft of the engine fairing).

Internal Noise: Comparisons of noise levels by octave bands are shown in Figure 48, page 69. The plottings shown in this illustration, like similar plottings of the CH-21C, represent the noise exposures (by octave bands) as measured at various internal station positions within a CH-37B during normal cruise. The engines were operating at 2,600 rpm and 38 inches of manifold pressure. The main rotor was rotating at 184.4 rpm and the tail rotor was revolving at 866.7 rpm. The transmission, which is located directly beneath the main rotor (the fourth vertical plotting from the left), generates rather intense noise levels. The character of the noise emitted from the main transmission unit encompasses a wide frequency range. If the reader will follow the noise plottings for each octave band beginning at 600 cps, it is clearly evident that as these frequencies approach the area of the main transmission the acoustical energy contained within the various bands increases. Further, as the plottings are followed past th_ transmission unit, the levels within these frequency bands decrease. The presence of exhaust noise is most evident in the 75 to 150, 150 to 300, and 300 to 600 cps octave bands, and becomes most pronounced at locations aft of the engine nacelles.

Figure 49, page 70, shows examples of noise generated beneath the main transmission unit of the CH-37B during various phases of power operation. The transmission section contains a two-stage gear-reduction unit with an outer bell gear assembly that is quite large. The rotors receive a 14.1-to-1 total gear reduction from the transmission. The noise generated within the transmission unit is determined to a

great extent by the amount of torque being delivered to the main rotor, as well as by relative gear and shaft speeds of components contained within the housing of the main transmission. The influence of engine and shaft torque on the total noise generated within the unit during lift-off, a maneuver in which rather high values of torque are applied to the rotor blades through the transmission section, is most intense in the 150 to 300 cps frequency range. Figure 50, page 71, shows noise measurements completed at various internal positions during normal cruise. Noise emanating from the main rotor as well as from the main transmission unit is quite pronounced at the position located between the first windows within the passenger-cargo area. At a center position between the third windows, noise generated by the transmission and the exhausts of the engines are most evident. Measurements made at a center position between the fourth window and the door demonstrate the presence of distinct noise components generated by the main rotor and engine exhaust although exhaust noise is somewhat less significant at this particular location.

External Noise: Essentially, the over-all external noise of the CH-37B is composed primarily of acoustical energies generated by the engines, the main rotor, and the antitorque tail rotor. Figure 51, page 72, illustrates noise levels measured at three external locations near a CH-37B helicopter during ground run-up at a distance of 100 feet from the center line of the aircraft. The engines were operating at 2,600 rpm and the main rotor was rotating at approximately 184.4 rpm. The magnitude of the noise progressively increases as one moves toward the rear of the helicopter. This progressive increase is due to the added influence of acoustical energies emanating from the engine exhaust, main rotor, and antitorque rotor. For instance, engine exhaust noise is most pronounced at locations aft of the engine exhaust ports and antitorque rotor noise disturbances are most intense at locations near the tail rotor. As noted, noise generated by the CH-37B during ground operations is most distinct in the lower frequency ranges.

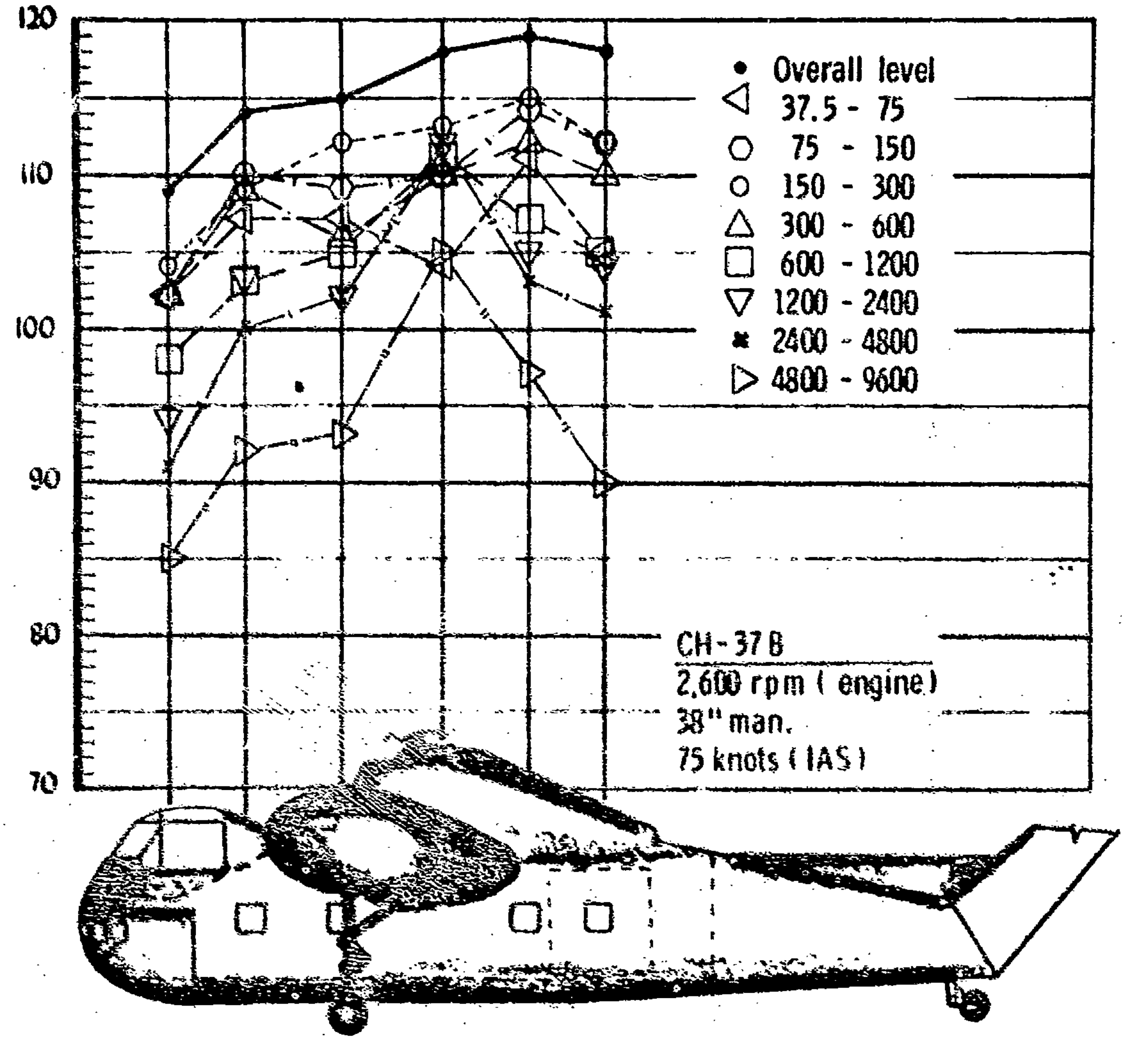

Fig. 48 Internal Noise of CH-37B Helicopter During Normal Cruise at 1000' Altitude, 75 Knots IAS

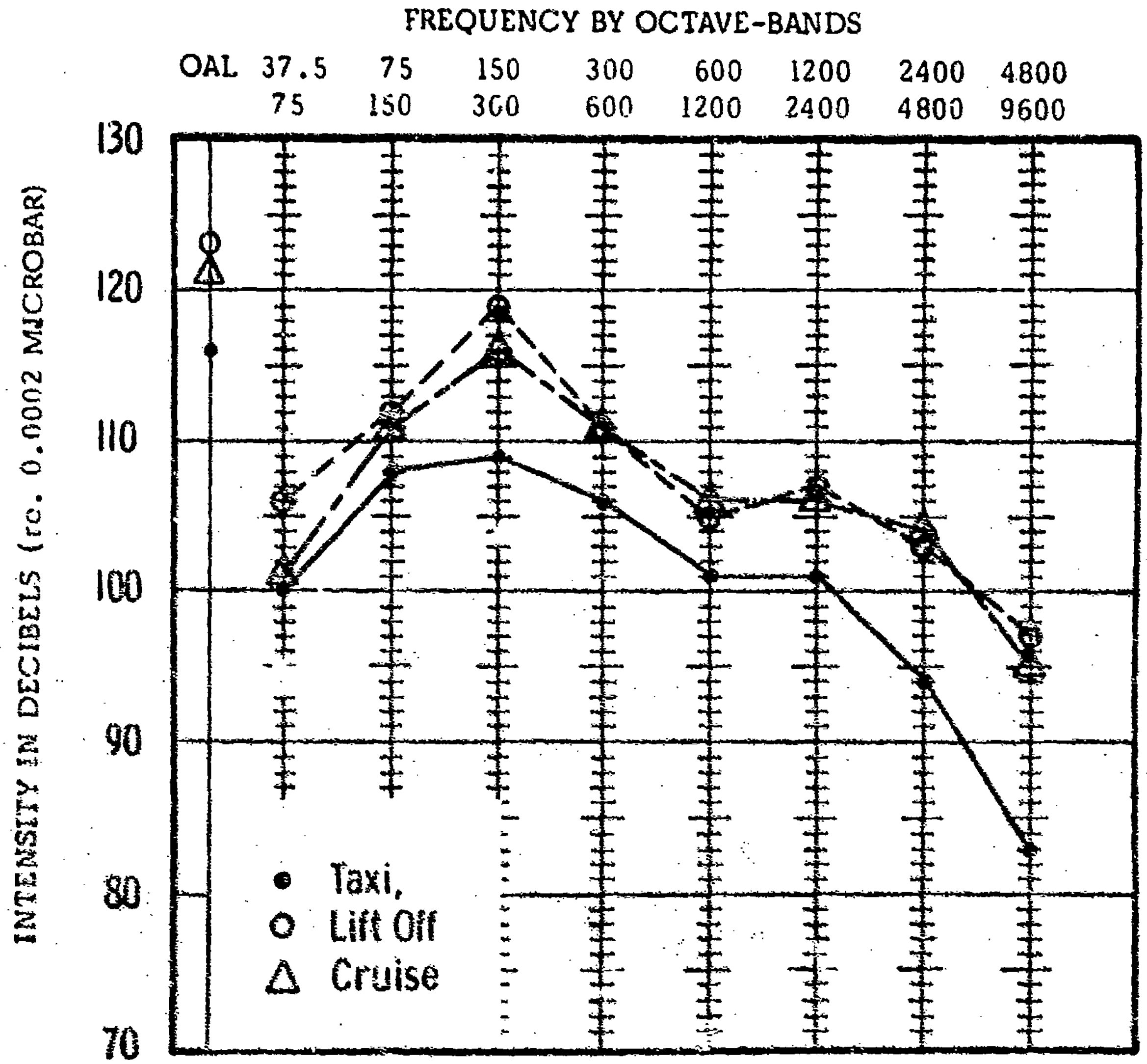

Fig. 49 Internal Noise of CH-37B Helicopter During Taxi, Lift-Off, and Normal Cruise

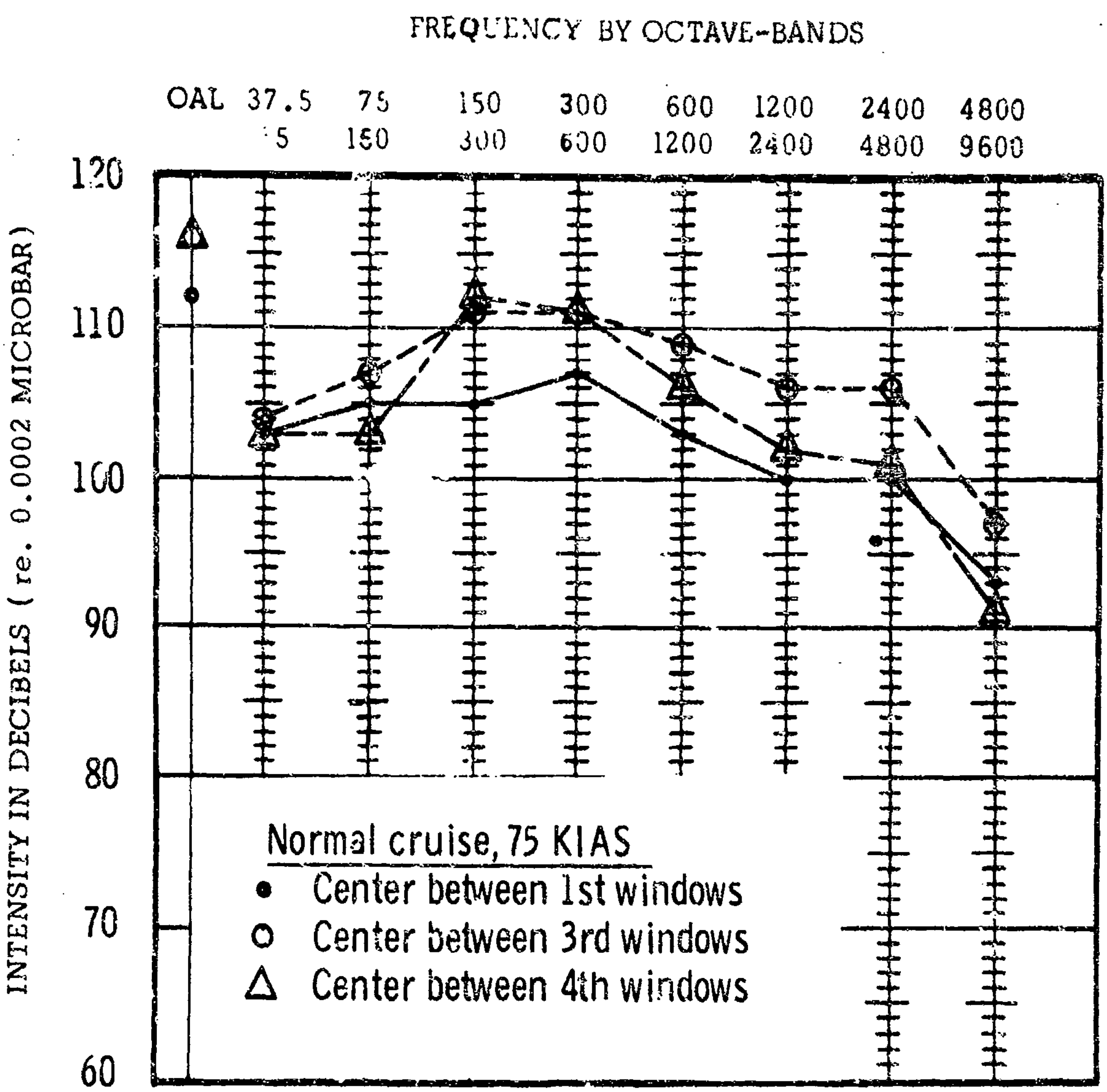

Fig. 50 Internal Noise of CH-37B Helicopter During Nomal Cruise, 2600 RPM, 38" MP

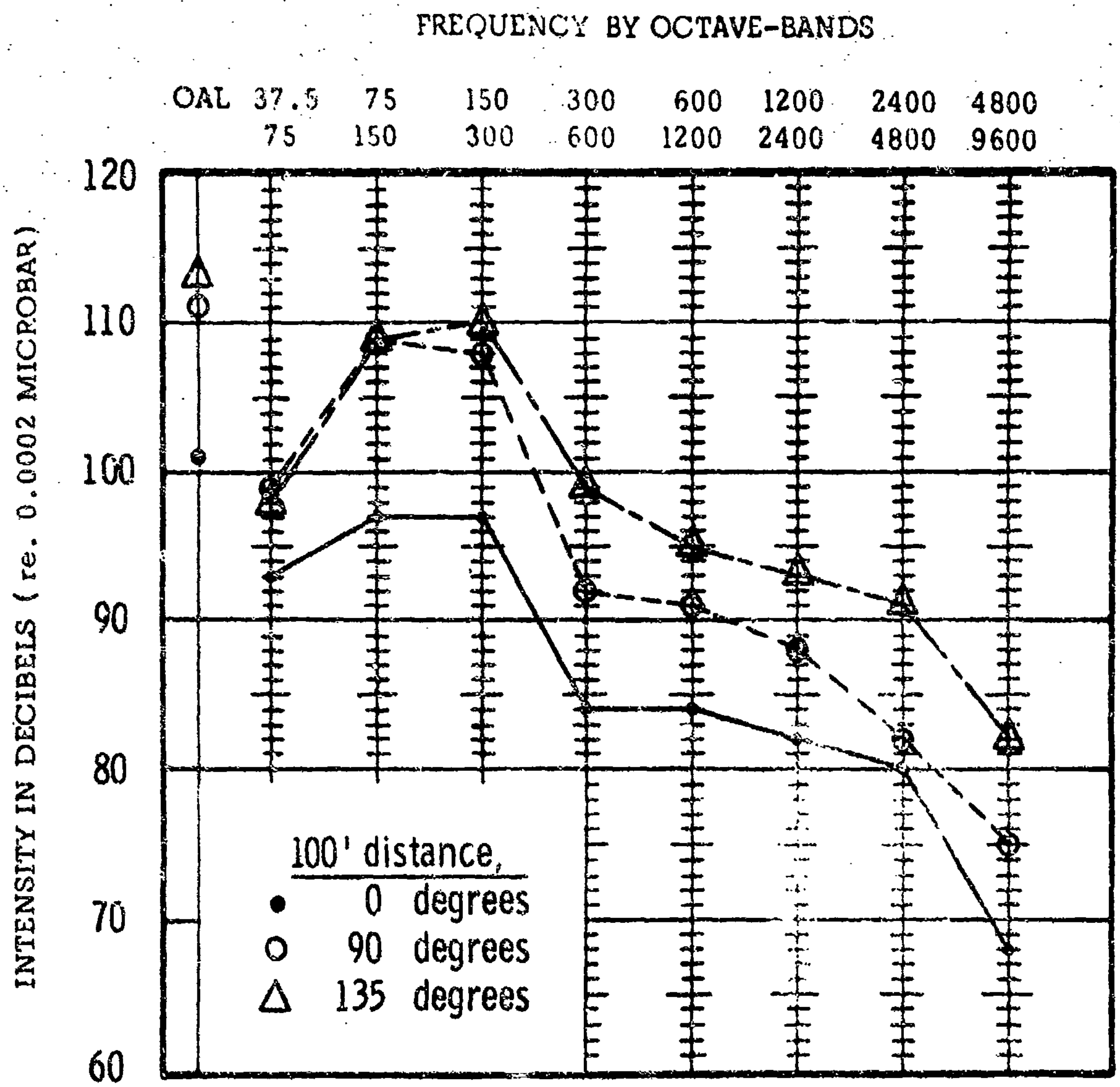

Fig. 51 External Noise of CH-37B Helicopter During Ground Run-Up, 2600 RPM

CH-47A.

The CH-47A is a large tandem-rotor helicopter powered by two gas-turbine engines. The power plants are Lycoming T55-L-5 turboshaft engines which produce approximately 2,200 shaft horsepower at 18,750 rpm at maximum rated power and approximately 1,850 shaft horsepower at 18,210 rpm at normal rated power. A slight amount of jet thrust, approximately 250 pounds of thrust at maximum power and 218 pounds of thrust at normal power, is produced by the engine exhaust. Each rotor system consists of three blades and has a diameter of 58'2".

Internal Noise: The noise generated internally within the CH-47A is a mixture of many complex noise components. Figure 52, page 75, demonstrates noise levels at different station locations within a CH-47A during normal cruise. The engines were generating 350 psi of torque and the rotors were rotating at 230 rpm. The aircraft was flying at an altitude of 500 feet and at an airspeed of 100 knots (IAS). Plottings of the over-all noise levels show that at positions directly beneath the forward and aft transmission the level of the noise is found to be most intense. Noise plottings of the lower frequency band of 37.5 to 75 cps indicate positions where noise emanating from disturbances created by the rotors is found to be most intense. The noise plottings of the acoustical energy produced within the higher frequency ranges, especially from 1200 through 4800 cps, are indicative of noise generated by the forward and aft transmission and gear-distribution systems. For instance, at positions directly beneath the forward and aft transmission units the noise in the higher frequency ranges was found to be most pronounced. In fact, the noise plottings indicate that the level of the over-all noise at these internal locations is largely determined by the amount of acoustical energy produced by the transmission and related systems within the aircraft.

Figure 53, page 76, illustrates similar noise plottings taken at the same internal positions. However, during these measurements the aircraft was operating on the ground and the engines were producing only 150 pounds of torque. When less torque is applied to the transmission systems, and subsequently the rotors, the level of the noise produced by the transmissions remains basically the same, except for the forward transmission system. As noted from these measurements, the noise generated by the forward transmission system is not as intense during low power ground operations as it is during higher power cruise conditions. In contrast, noise emanating from the aft transmission system remains basically the same throughout both phases of operation.

Figure 54, page 77, depicts results of noise measurements within the CH-47A during ground operations. These measurements were recorded within the vehicle on the left side of the helicopter (third window, troop seat position) at head level. These plottings illustrate the noise generated by the auxiliary power unit during

pre-start of the engines. The auxiliary power unit (APU) is located in the aft section of the fuselage and is mounted in the lower portion of the aft rotor pylon. The intake and duct leading to the APU are located on the mid right side of the aft rotor housing pylon and the exhaust port is located in the extreme aft center of the upper rear fuselage. Normally, the APU operates only during ground operations prior to and during engine starting and is turned off during flight. The APU provides shaft power for starting the engines and thus produces both mid (600 to 1200 cps) as well as high frequency (4800 to 9600 cps) noise components. When the APU is off and the rotors are operating, the generation of lower frequency noise components, especially below 300 cps, becomes evident.

Examples of transmission type noise are illustrated in Figure 55, page 78. These plottings represent the noise generated at positions directly beneath the forward and aft transmission systems within the CH-47A during ground operations. Noise measured at aft transmission locations is a mixture of acoustical components generated by the main transmission and gear-reduction units, the rotating components of the engines, the engine-to-transmission combining-transmission unit, and shaft-distribution bearings and supports.

Figure 56, page 79, illustrates differences in noise levels existing at the center and right locations between the rear fifth windows during a hover. The differences in noise exposures produced at center and side positions are due primarily to acoustical modifying actions created by differences in internal resonance characteristics of the helicopter and to the proximity of the observer to a particular noise generating mechanism. For instance, center line noise measurements show the influence of proximity of the observer to the noise generated in the higher frequency ranges by the transmission and torque shaft-distribution systems.

The noise envelope, as shown in Figure 57, page 80, depicts the range of noise levels existing at different internal positions from the front to the rear of the helicopter during normal cruise. These measurements were completed while the helicopter was flying at an altitude of 500 feet and an airspeed of 100 knots (IAS).

External Noise: The external noise produced near a CH-47A helicopter is a combination of noise components generated by the rotors and engines. Figure 58, page 81, depicts results of noise measurements taken at a distance of 50 feet while the helicopter was on the ground at power settings normally employed during troop discharge. During this maneuver the rotors (and engines) are operated at a slightly higher power setting than that normally used for regular ground idle. Noise levels recorded directly at the side of the helicopter represent the most intense noise levels recorded during this maneuver.

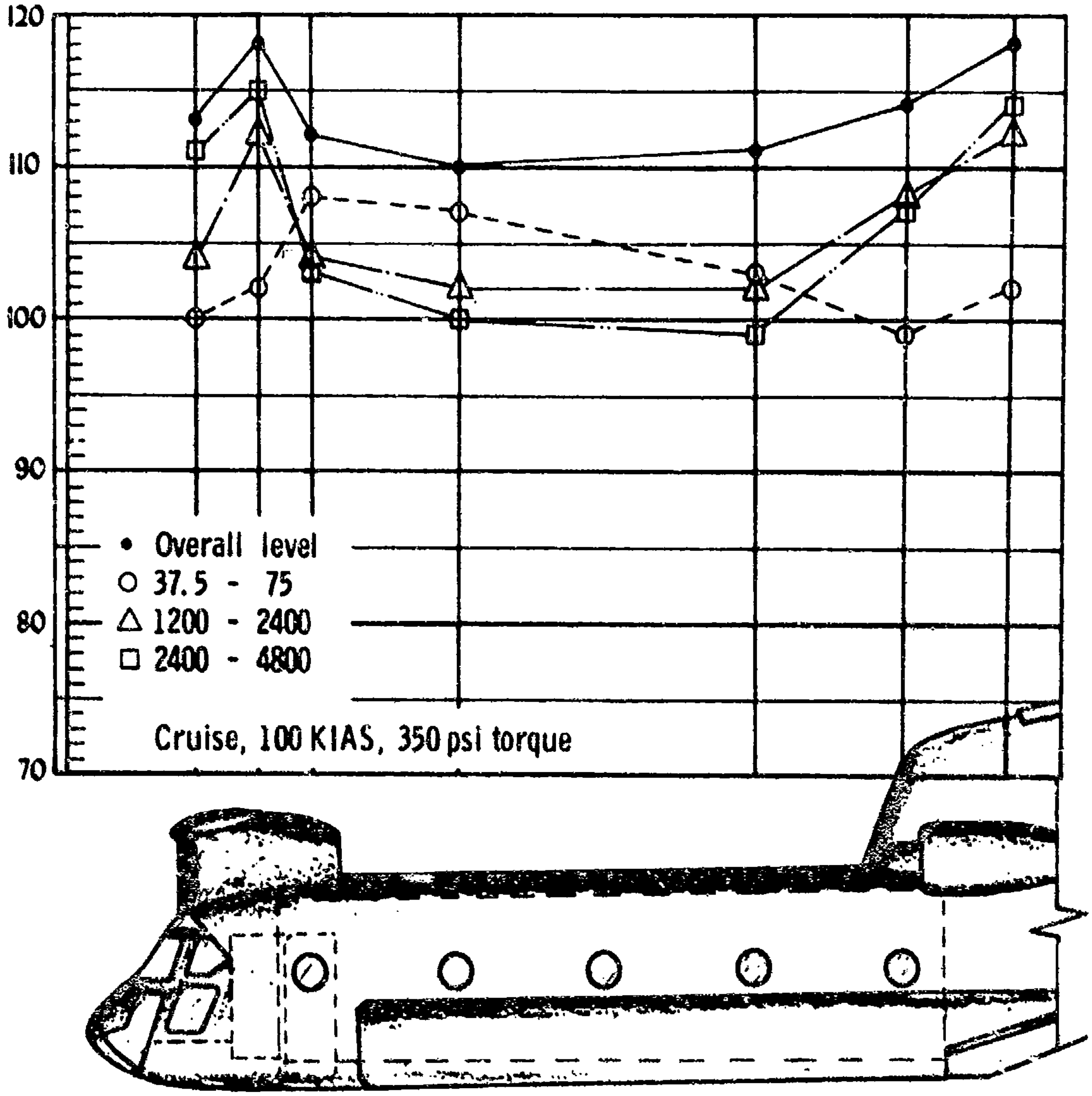

Fig. 52 Internal Noise of CH-47A Helicopter During Normal Cruise at 500' Altitude, 350 PSI Torque, 100 Knots IAS

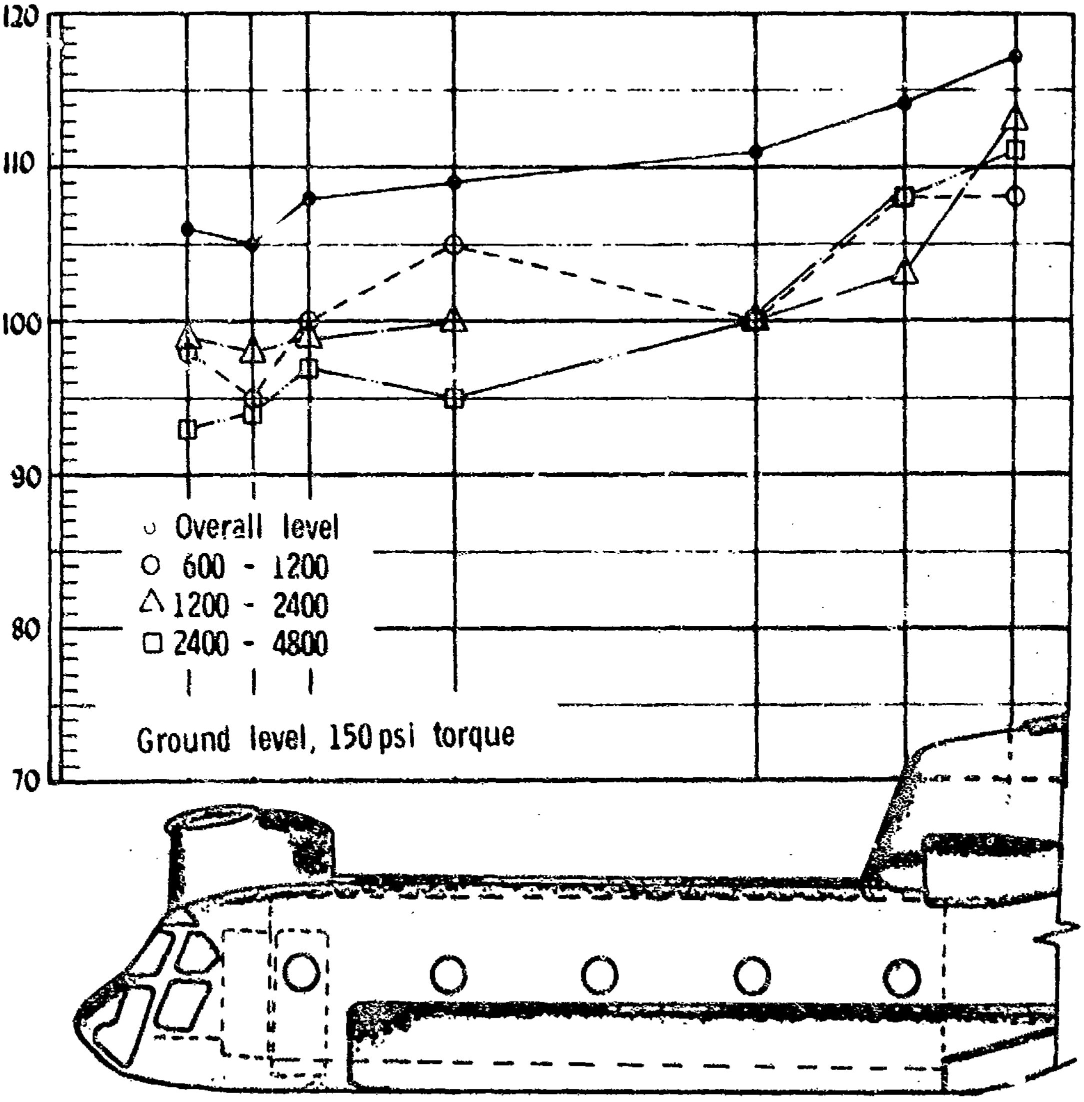

Fig. 53 Internal Noise of CH-47A Helicopter During Ground Operations, 150 PSI Torque

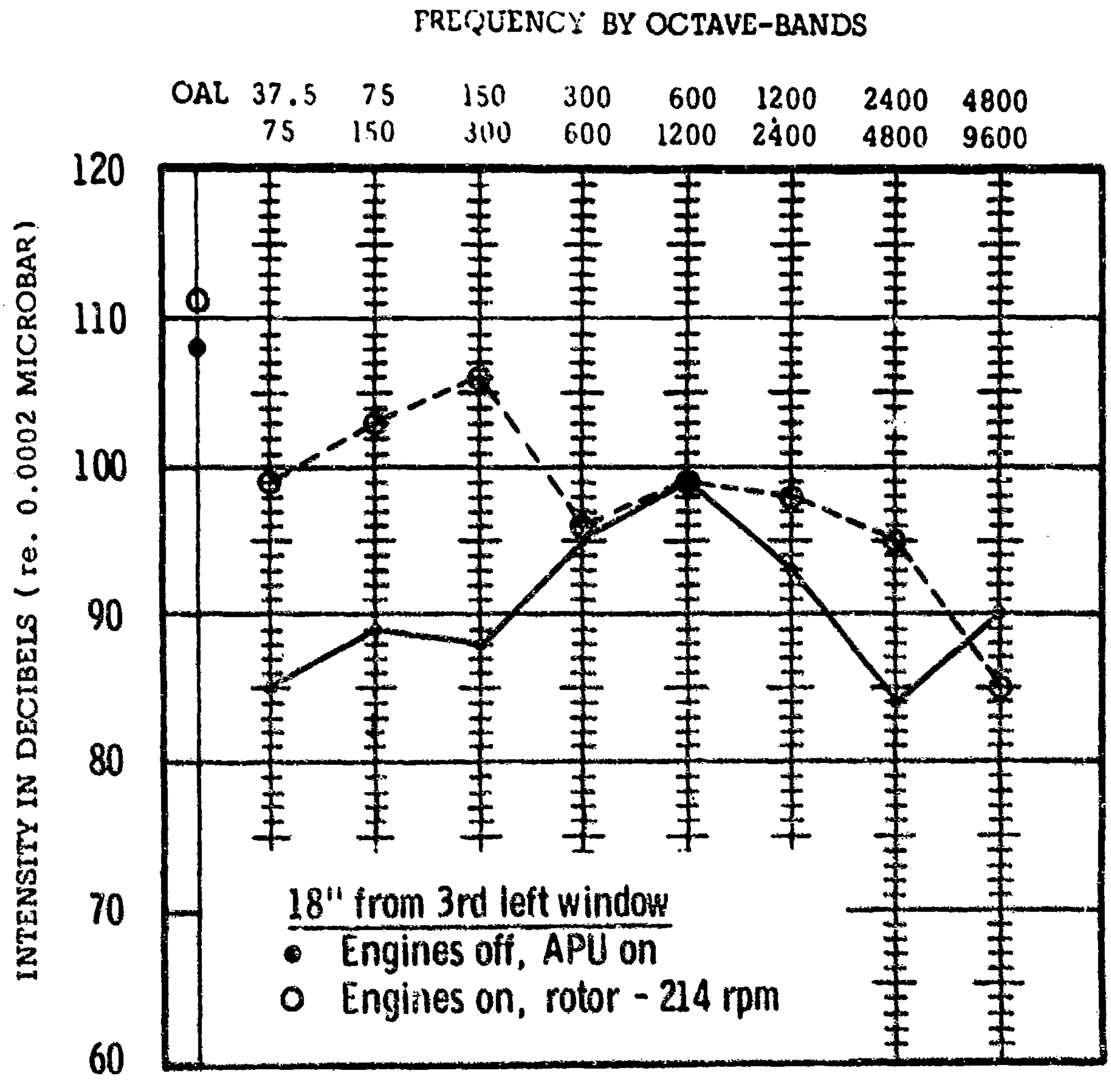

Fig. 54 Internal Noise of CH-47A Helicopter During Ground Operations

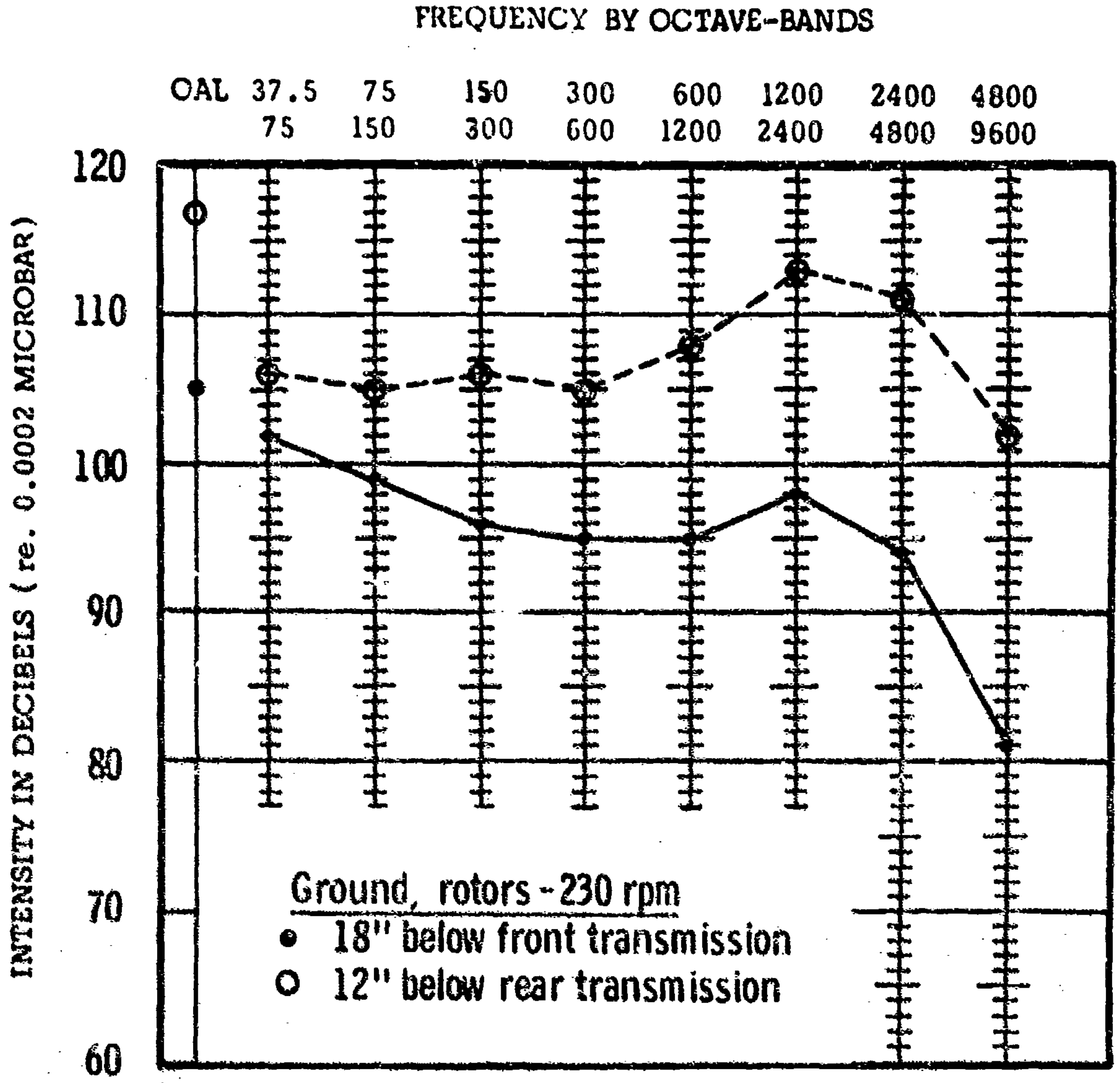

Fig. 55 Internal Noise of CH-47A Helicopter During Ground Operations, 150 PSI Torque

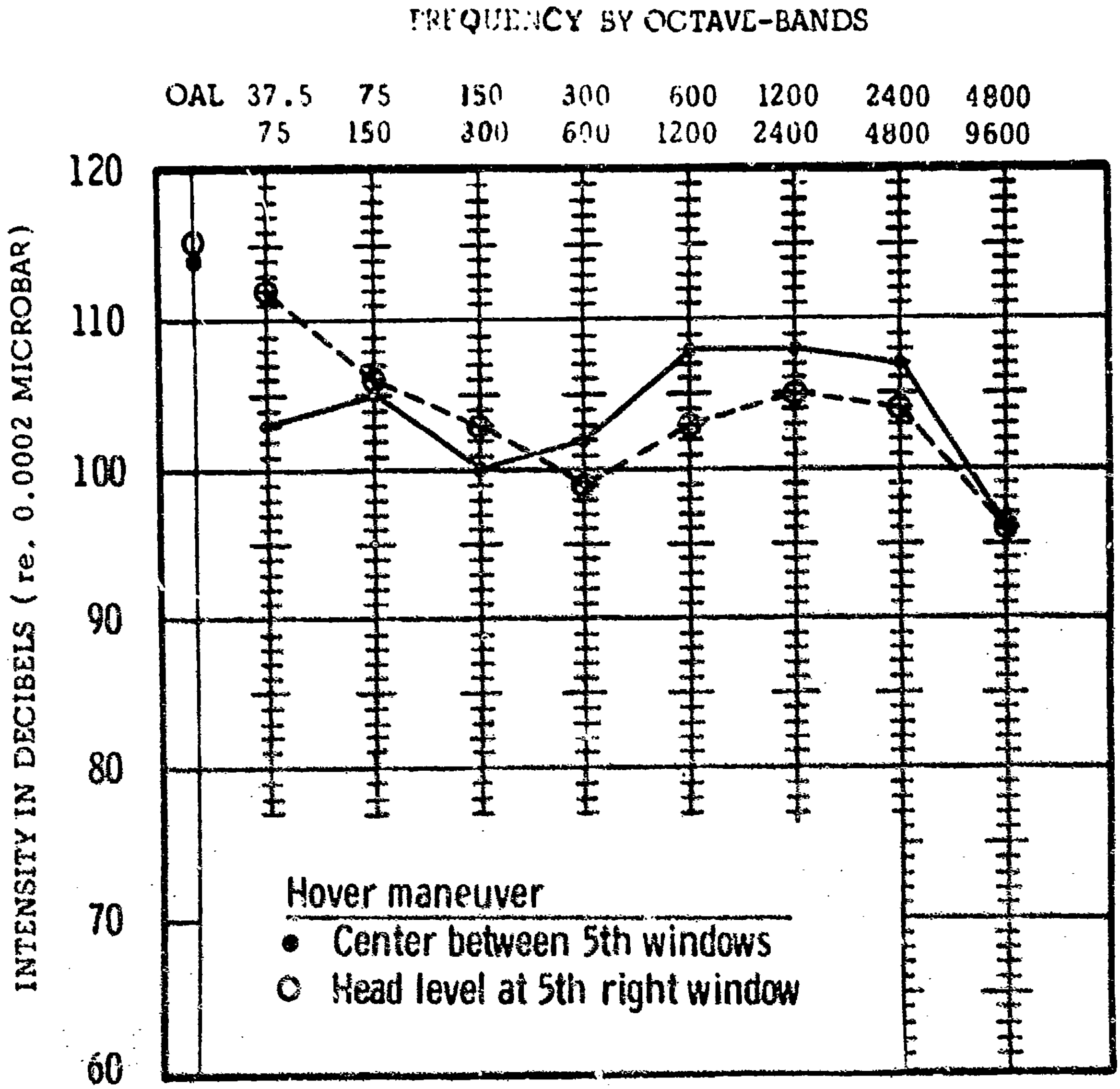

Fig. 56 Internal Noise of CH-47A Helicopter During a Hover, 83.5%, 280 PSI Torque

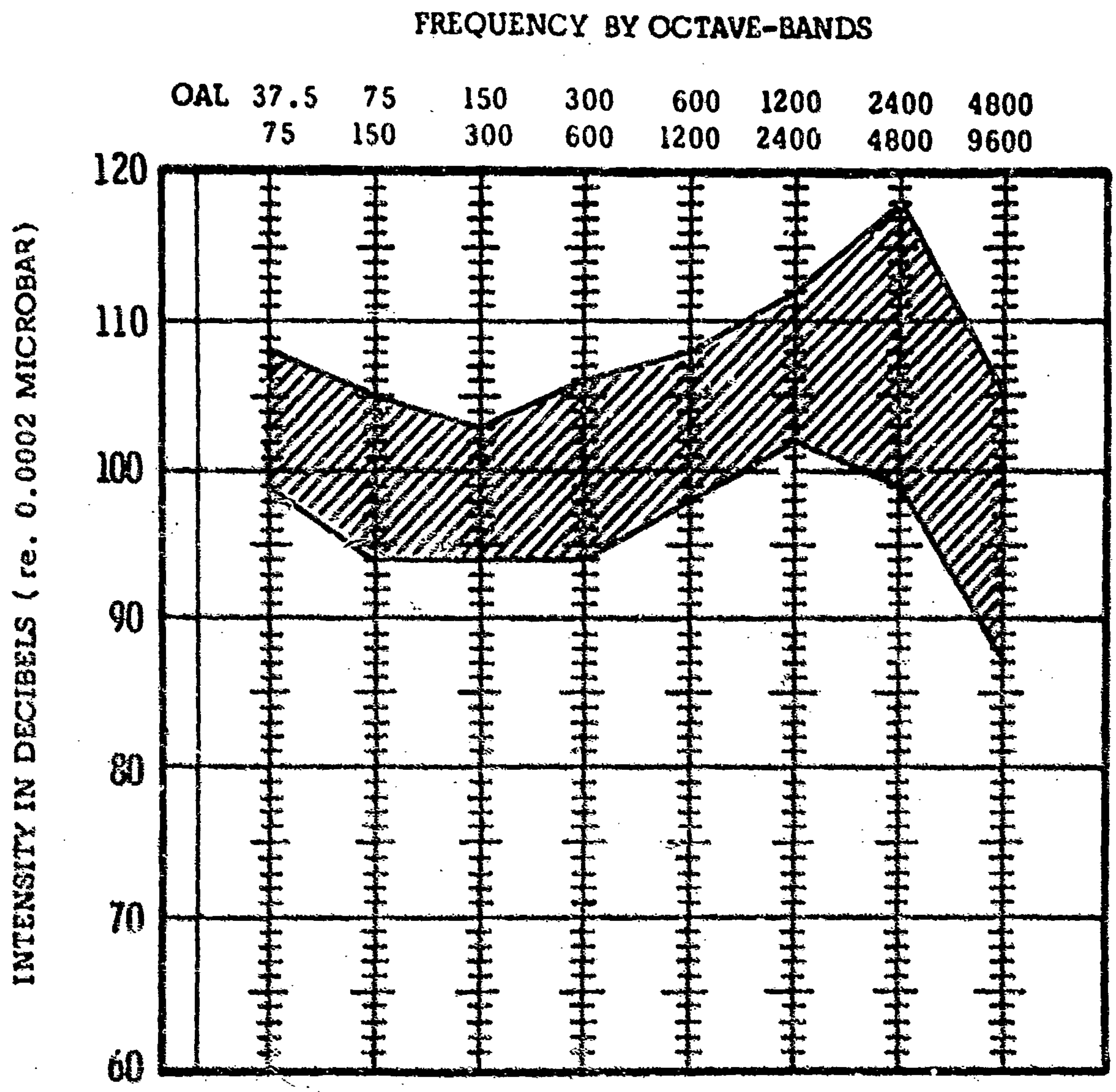

Fig. 57 Internal Noise of CH-47A Helicopter During Normal Cruise at 500' Altitude, 83%, 350 PSI Torque, 100 Knots IAS

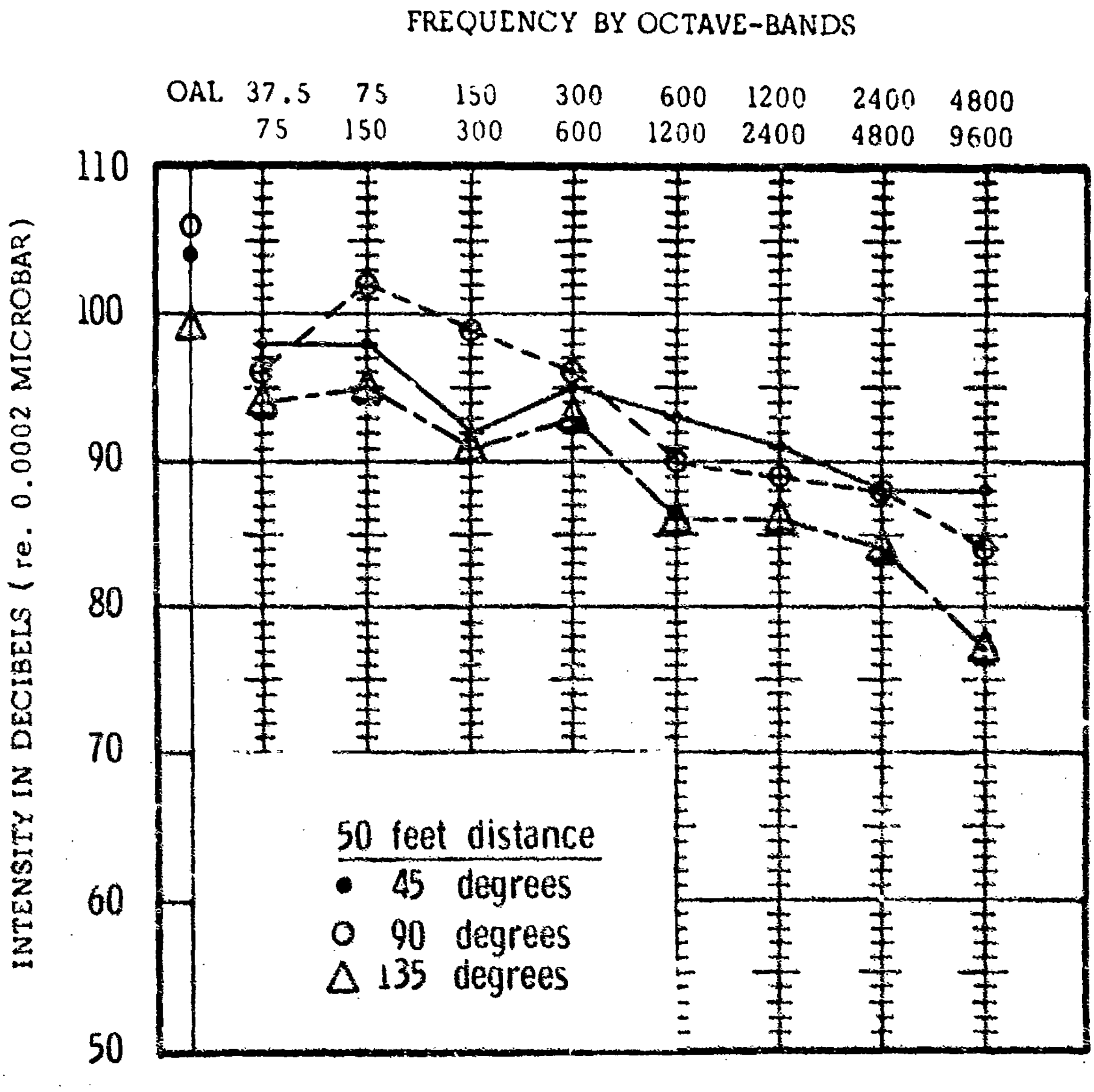

Fig. 58 External Noise of CH-47A Helicopter During Ground Operations

2. FIXED-WING AIRCRAFT.

A. Utility Aircraft

U-1A.

The DeHavilland U-1A aircraft is powered by a single Pratt and Whitney R1340 radial type reciprocating engine capable of producing approximately 600 brake horsepower at 2,250 rpm at maximum take-off power and a normal rated power of 550 brake horsepower at 2,200 rpm.

Internal Noise: Noise generated within the aircraft is the product of noise components emanating from the engine, exhaust, and propeller. These primary noise generators distribute their most intense acoustical energy in the lower frequency ranges. The noise plottings in Figure 59, page 85, illustrate the general distribution of noise as measured at various internal locations in a U-1A during normal cruise. The aircraft was flying at an altitude of 5,000 feet and an airspeed of 100 knots (IAS). The engine was operating at 1,800 rpm and 28 inches of manifold pressure. The engine provides a gear reduction of 0.667-to-1, thus, the propeller shaft was rotating at 1,267 rpm when the engine shaft was operating at 1,800 rpm. The propeller consists of three blades and has a total diameter of 11'0". When the engine is operating at 1,800 rpm the propeller tips have a fundamental blade passage frequency of 63.4 times per second and a blade tip velocity of approximately 729.8 feet per second (0.653 Mach). The noise plottings indicate the general distribution of the over-all noise level as well as the acoustical energies between 37.5 through 300 cps as measured at various internal locations. At the pilot position noise emanating from disturbances created by the propeller is most dominant. Also, at this location the presence of internal structural and compartment resonances are noticeable. The aerodynamic disturbances produced by the propeller blades as they impinge upon the front windshield also contribute to the noise created within the pilot compartment. The U-1A has four exhaust augmentor tubes that are located on the lower right and left sides of the aircraft. The use of exhaust augmentor tubes provides additional engine cooling when the engine is operating at low power. Due to their location exhaust expulsions dump out of the tubes at a position directly behind and below the pilot compartment. Noise emanating from the exhaust is most noticeable at positions within the passenger-cargo area which is located above and aft of the exhaust ports. Exhaust noise is most dominant in the 37.5 through 75 cps frequency range. Located beneath the floor of the forward passenger-cargo area are four individual cell-type fuel tanks. When filled, these tanks may serve to offer some degree of noise damping, but as fuel is consumed, the tanks not only offer less obstuction to the intrusion of the exhaust noise but may also act as acoustical resonators. If acoustical resonance occurs a slight increase in exhaust noise within the aircraft may be noted.

Figure 60, page 86, illustrates plottings of noise generated in the right (pilot) seat position during both climb and normal cruise. The general frequency spectrum of the noise remains basically the same and only the general intensity level of the noise tends to change during these two phases of flight. The peak noise generated within the 75 to 150 cps octave band range is the major determiner of the level of the over-all noise. The noise present within this frequency range is generated by the propeller, the engine, and the exhaust of the engine. It should be remembered that since the engine is directly mated to the main fuselage and is located directly in front of the pilot compartment, noise generated within the components of the engine is propagated directly through the main structures of the aircraft. Noise exposures generated within the passenger-cargo area are shown in Figure 61, page 87. These measurements were taken within the forward and middle sections of the passenger-cargo area during high power operation of the engine. The noise levels recorded in the forward section of this area are more intense than the levels recorded in the aft sections due to the increased power required during take-off and due to the closer proximity of occupied areas to the exhaust and propeller. The noise plottings in Figure 62, page 88, illustrate the differences in noise exposures recorded at right, left, and center locations at the same station position. These levels were recorded while the aircraft was flying at an altitude of 5,000 feet and an airspeed of 100 knots (IAS). The engine was operating at 1,800 rpm and 28 inches of manifold pressure. The noise levels recorded in the 75 to 150 cps octave band are more intense at locations near the sides of the fuselage because of the closer proximity to the exhaust ports. A major factor is the influence of the relative wave lengths represented within these low frequencies, but this influence, although present, is difficult to assess. Plottings in Figure 63, page 89, represent noise exposures measured at various locations from the front to the rear of the passenger-cargo area. These measurements were taken while the aircraft was operating at normal cruise. As noted, the noise exposures are relatively the same from the front to the rear. Generally, as one moves to the aft section of the compartment the level of the over-all noise tends to decrease.

External Noise: Figure 64, page 90, depicts results of noise measurements taken at various angular locations at a distance of approximately twelve feet from the propeller hub of a U-1A during ground operation. During these measurements the engine was operating at 1,000 rpm and 17.5 inches of manifold pressure. At a location directly in front of the propeller the presence of both vortex and rotational noise is quite evident. At positions to the side of the propeller the general pattern of the noise differs, and as one moves to locations aft of the propeller, the influence of propeller blade pitch is highly important. At a position 135 degrees from the front of the aircraft the noise is a mixture of acoustical components generated by the propeller and exhaust. During these measurements the exhaust has a fundamental discharge rate of approximately 75 times per second and the propeller

had a blade passage frequency of 384.2 feet per second. An example of the difference in noise exposure that may result from changes in blade pitch is shown in Figure 65, page 91. These noise plottings were taken at a position of 135 degrees and a distance of twelve feet from the propeller hub. As blade pitch increases the level of the noise produced by the propeller also increases. Although the basic features of the noise spectrum did not significantly change, the magnitude of the over-all noise was altered.

In general, the over-all noise generated by the U-1A aircraft is somewhat less intense during various power operations because of the basic characteristics of a three-blade propeller system. The three-blade propeller system of the U-1A reduces many of the higher frequency harmonics and also lessens the total intensity of the noise produced by the propeller.

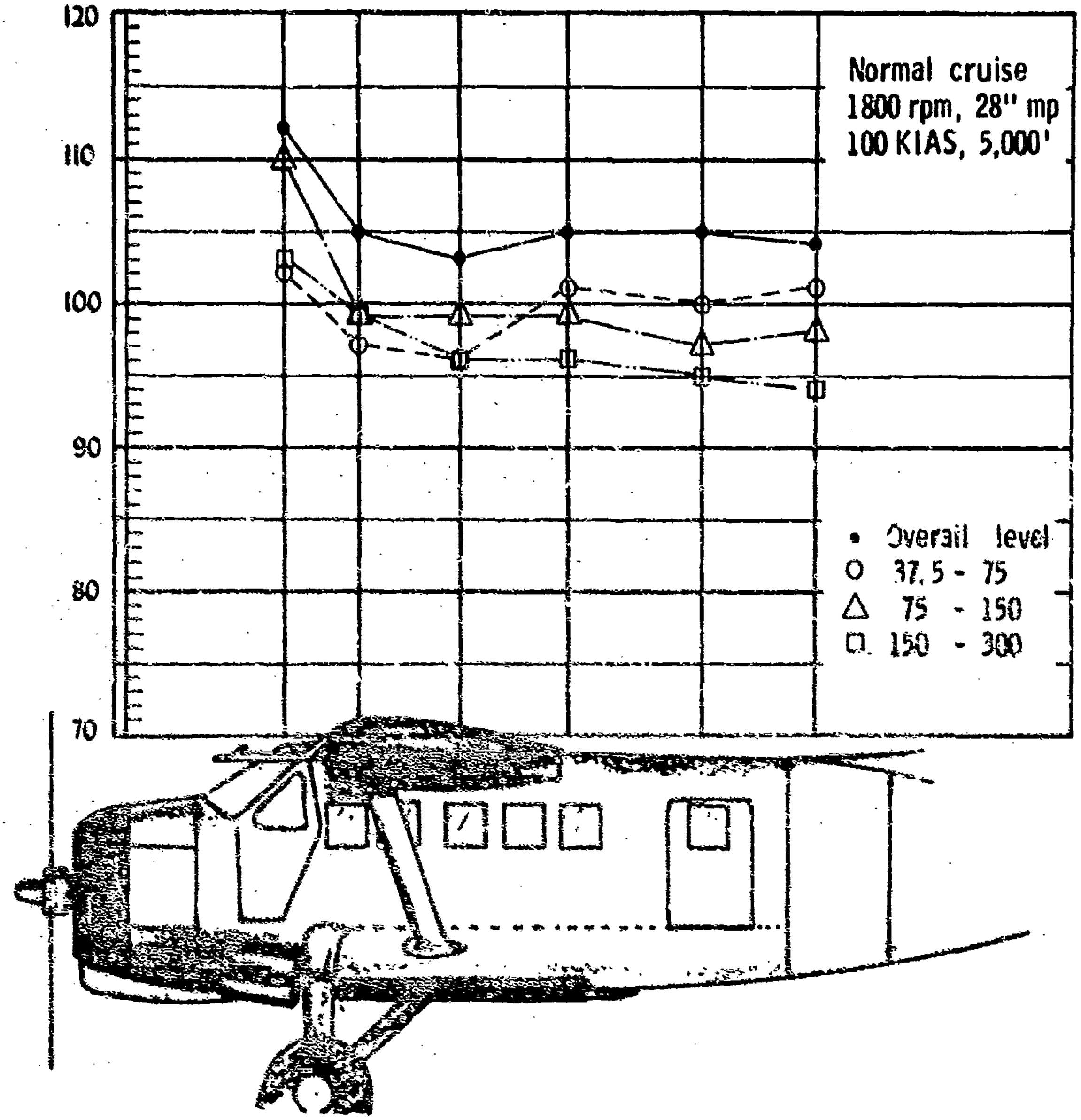

Fig. 59 Internal Noise of U-1A Aircraft During Normal Cruise at 5000' Altitude, 1800 RPM, 28" MP, 100 Knots IAS

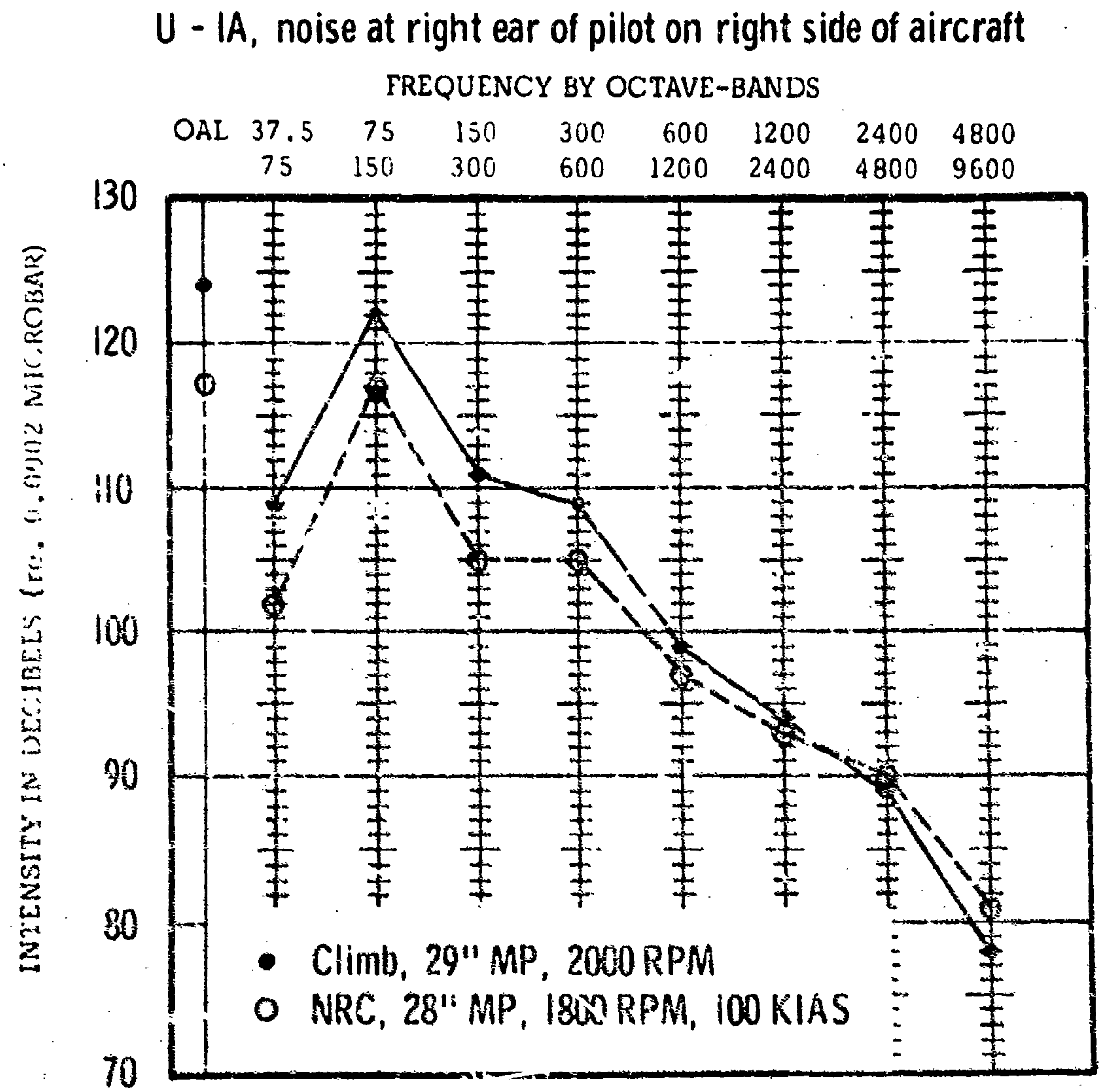

Fig. 60 Internal Noise of U-1A Aircraft During Climb and Normal Cruise

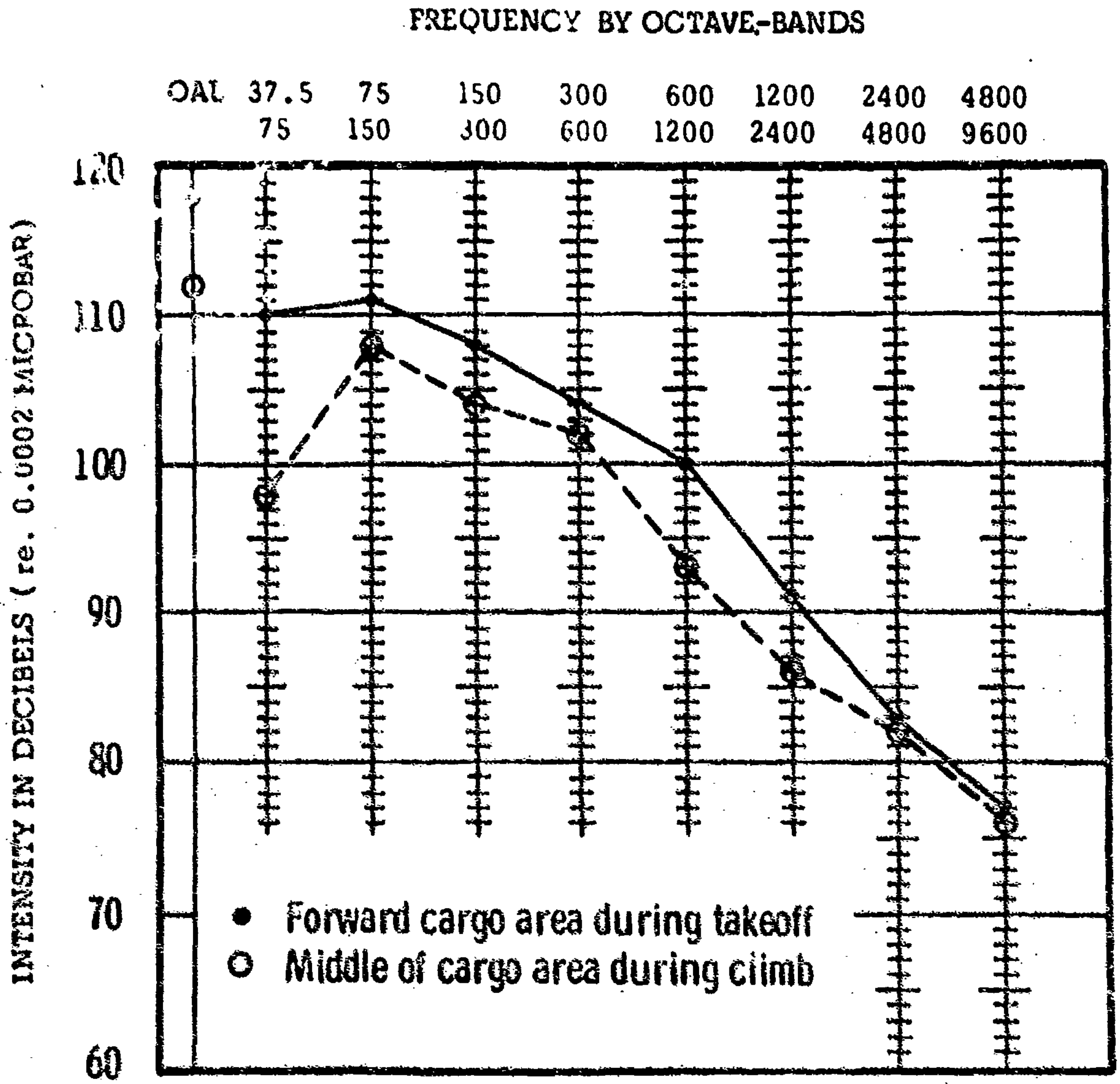

Fig. 61 Internal Noise of U-1A Aircraft During Take-Off and Climb, 2000 RPM, 30" MP

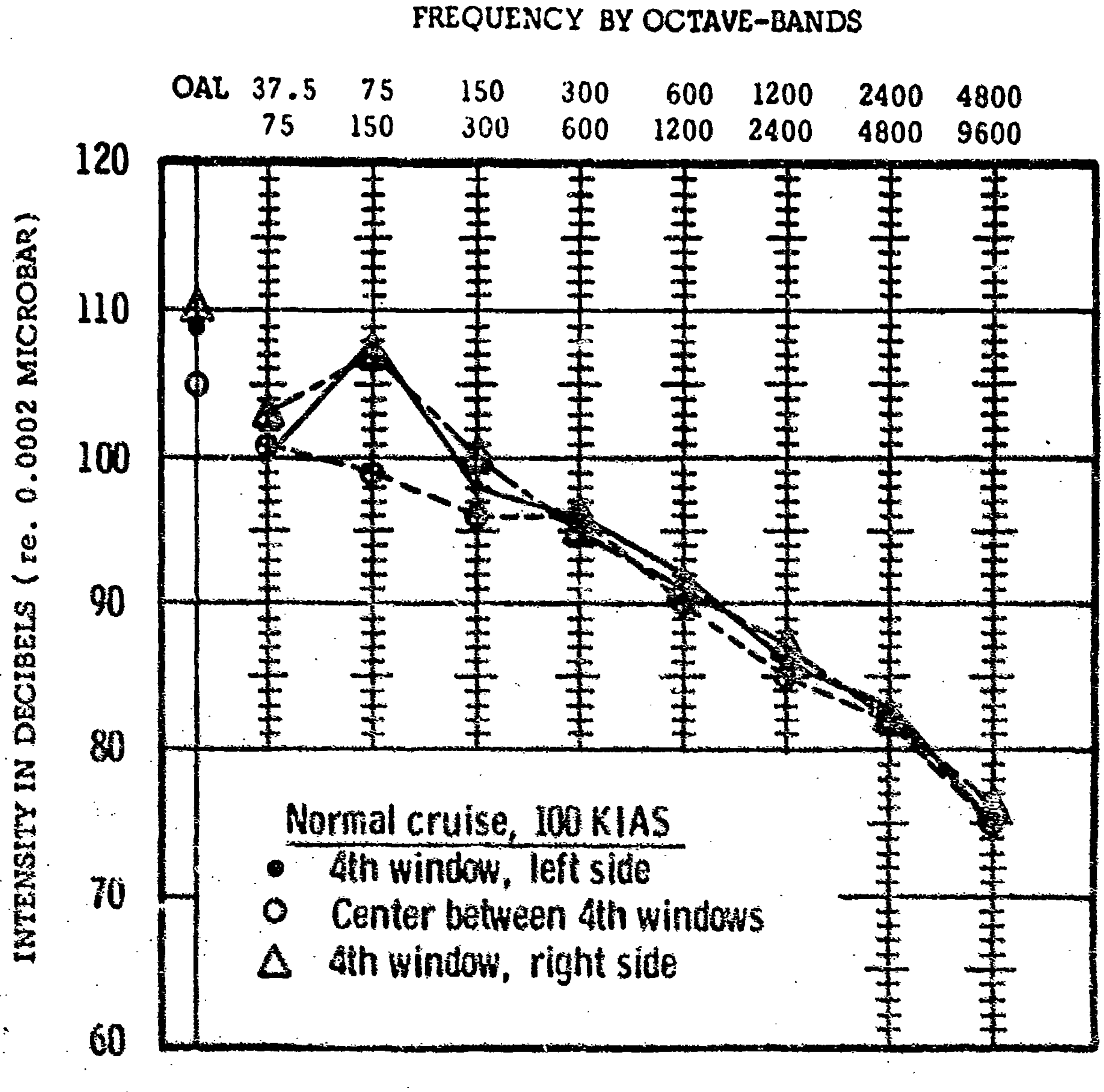

Fig. 62 Internal Noise of U-1A Aircraft During Normal Cruise at 5000' Altitude, 1800 RPM, 28" MP

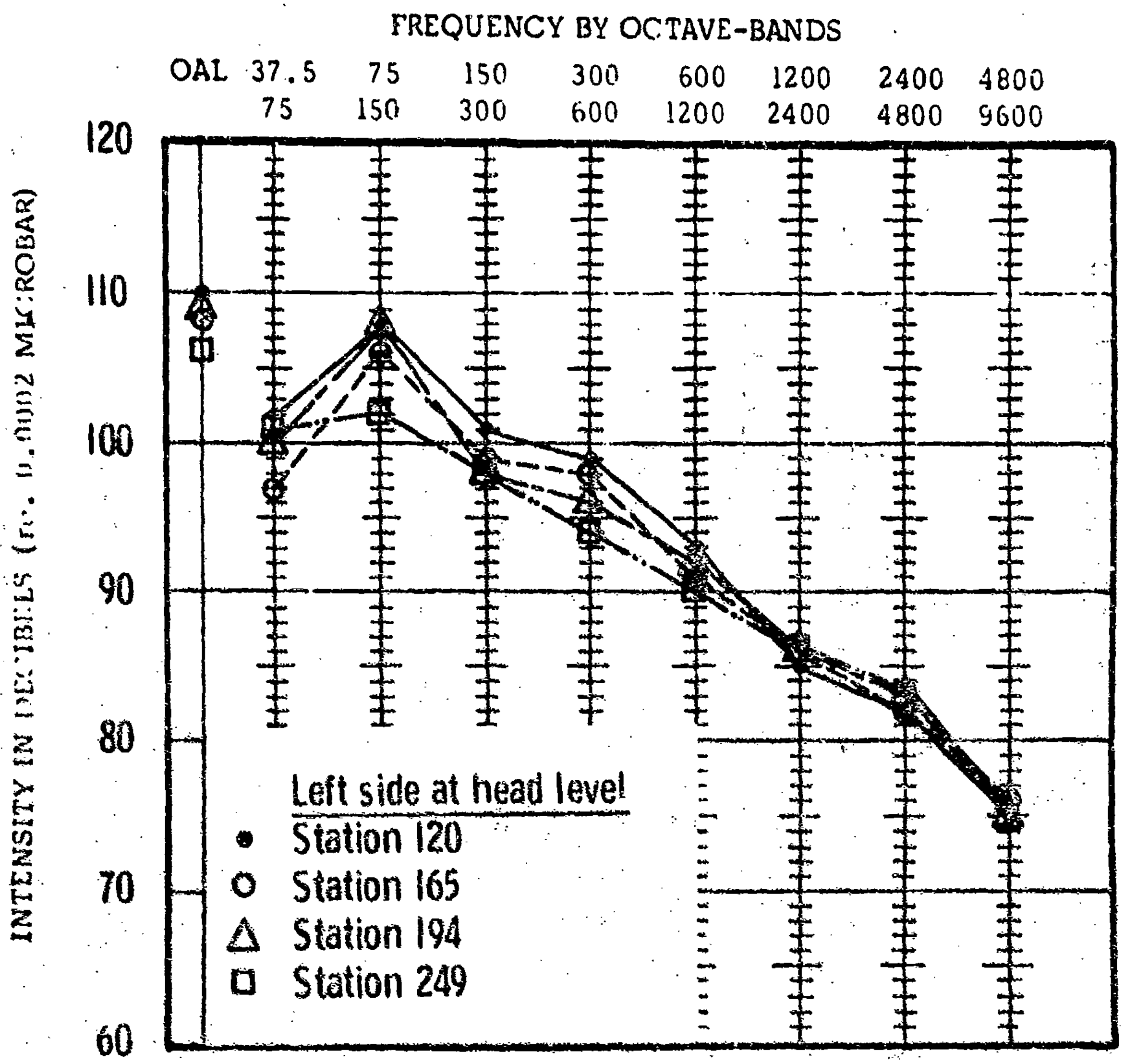

Fig. 63 Internal Noise of U-1A Aircraft During Normal Cruise at 5000' Altitude, 1800 RPM, 28" MP, 100 Knots IAS

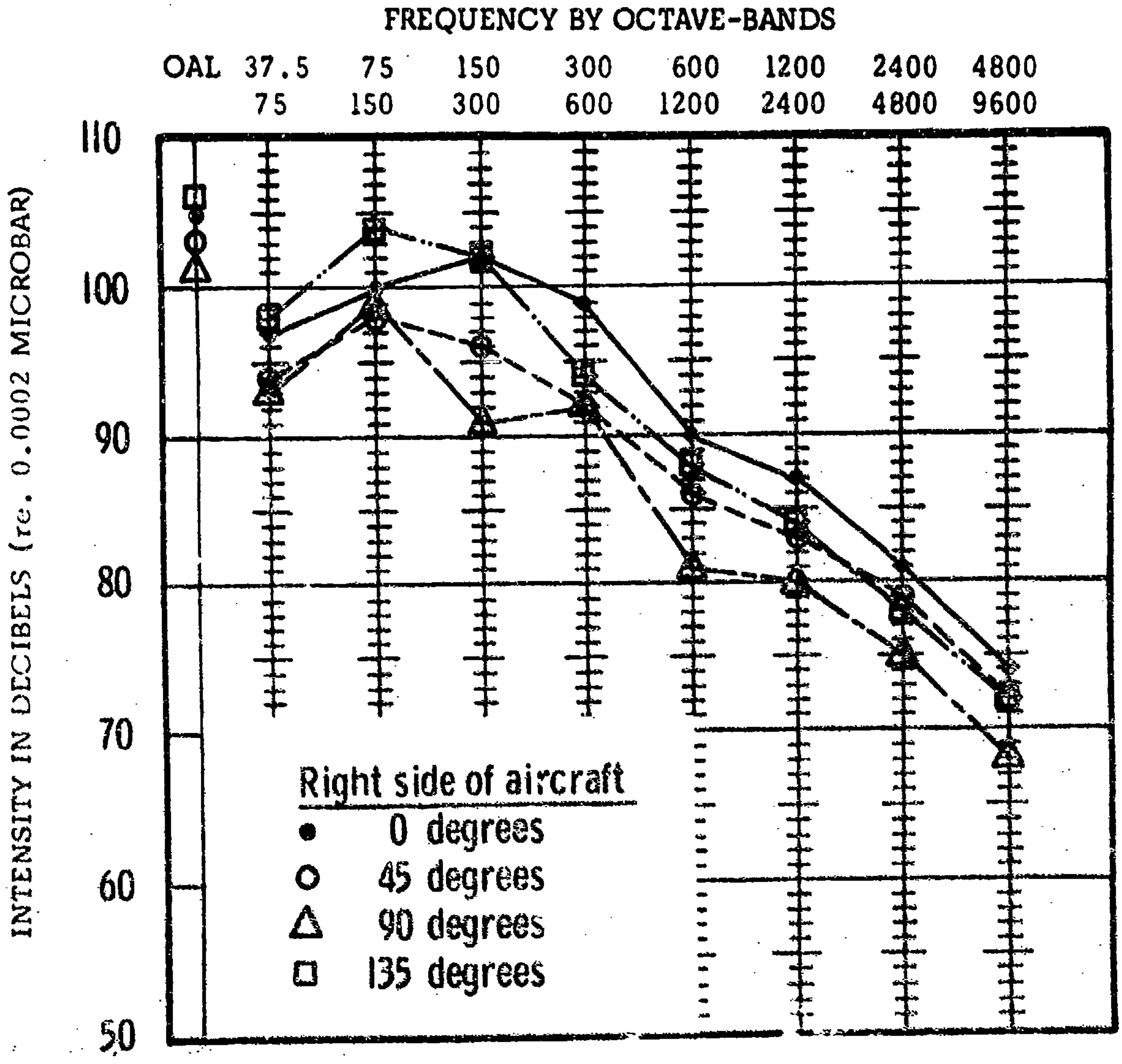

Fig. 64 External Noise of U-1A Aircraft During Ground Operations, Measured at 12' Distance, 1000 RPM, 17.5" MP

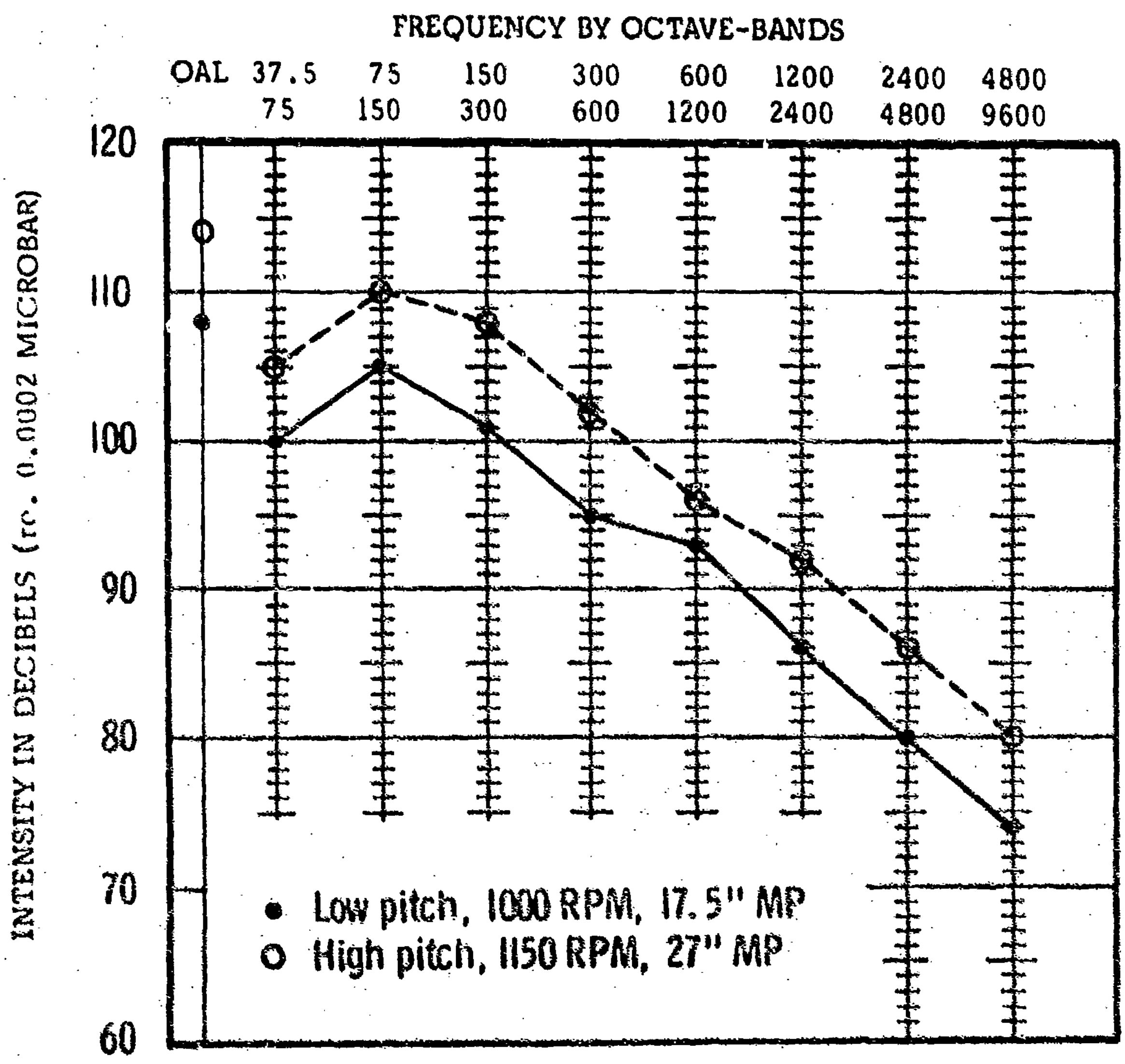

Fig. 65 External Noise of U-1A Aircraft During Ground Operations, Low versus High Propeller Pitch, Measured at 12' Distance, 135 Degrees

U-6A.

The U-6A is powered by a Pratt and Whitney R985 radial type reciprocating engine which can produce approximately 450 brake horsepower at 2,300 rpm at maximum power. The aircraft is fitted with a two-blade constant-speed Hamilton Standard propeller that has a diameter of 8'6". The engine provides direct drive shaft power to the propeller and the propeller pitch is variable so that relatively constant propeller speeds can be maintained.

Internal Noise: Figure 66, page 94, shows the results of noise measurements taken within a U-6A during three phases of flight: low, normal, and high cruise. The noise measurements were taken at ear level in the right pilot seat position. As the power required to achieve higher airspeeds is applied, the over-all level of the internal noise not only increases but also the general spectrum of the noise is altered. From low to normal cruise, the acoustical energy generated within the frequency range from 37.5 through 300 cps shifts into a higher frequency range progressively with increased power and, at higher power settings (maximum cruise), the noise level present within the three lower frequency bands is equally the same.

Figure 67, page 95, demonstrates the noise produced at various internal locations within a U-6A during normal cruise. At normal cruise the aircraft was flying at an altitude of 5,500 feet and an airspeed of 105 knots per hour (IAS). The engine was operating at 1,800 rpm and 28 inches of manifold pressure. The noise produced at left and right ear levels in the right pilot seat position is basically the same, except for the noise level in the 150 to 300 cps octave band. Naturally, the noise produced at the right ear is somewhat more intense than the noise level generated at the left ear because the right ear is closer to the side of the aircraft. The noise levels measured at the right side of the right rear section of the cargo area is illustrative of the influence of exhaust noise on the over-all internal noise. Figure 68, page 96, depicts the differences in noise exposures generated at the same internal station location but at right, left, and center positions. As noted, the most intense noise exposure was measured at the right side of the station position because [illegible] gle exhaust port of the engine exits on the lower right side of the engine.

External Noise: The external noise is a product of acoustical components emanating from the propeller and the exhaust of the engine. Figure 69, page 97, shows results of noise measurements taken at a distance of approximately ten feet from the propeller of a U-6A during ground level operation of the engine at 1,750 rpm. These measurements were taken at locations approximately 45 degrees behind the propeller plane. The noise exposures are basically the same as far as the over-all noise is concerned, but a noticeable difference in the acoustical spectrum of the noise between the two locations shows the influence of both engine exhaust and

propeller rotational noise components. On the right side of the engine (135 degrees) the exhaust noise is dominant in the frequency range below 300 cps and on the left side of the aircraft (225 degrees) the influence of blade pitch (rotational disturbances) is evident.

In general, the external noise produced by a U-6A during ground operations is distinctly audible. The two-blade propeller system of this aircraft produces a characteristic type of noise that is quite intense. Although the propeller tips have a lower fundamental frequency of blade passage than does a three-blade propeller at equal rpm, the two-blade propeller of the U-6A produces more pronounced higher frequency harmonics. During most of the operations of the U-6A where intense noise is produced, the noise emanating from the two-blade propeller is usually more subjectively noticeable than the noise of three-blade propellers operating at a similar rpm.

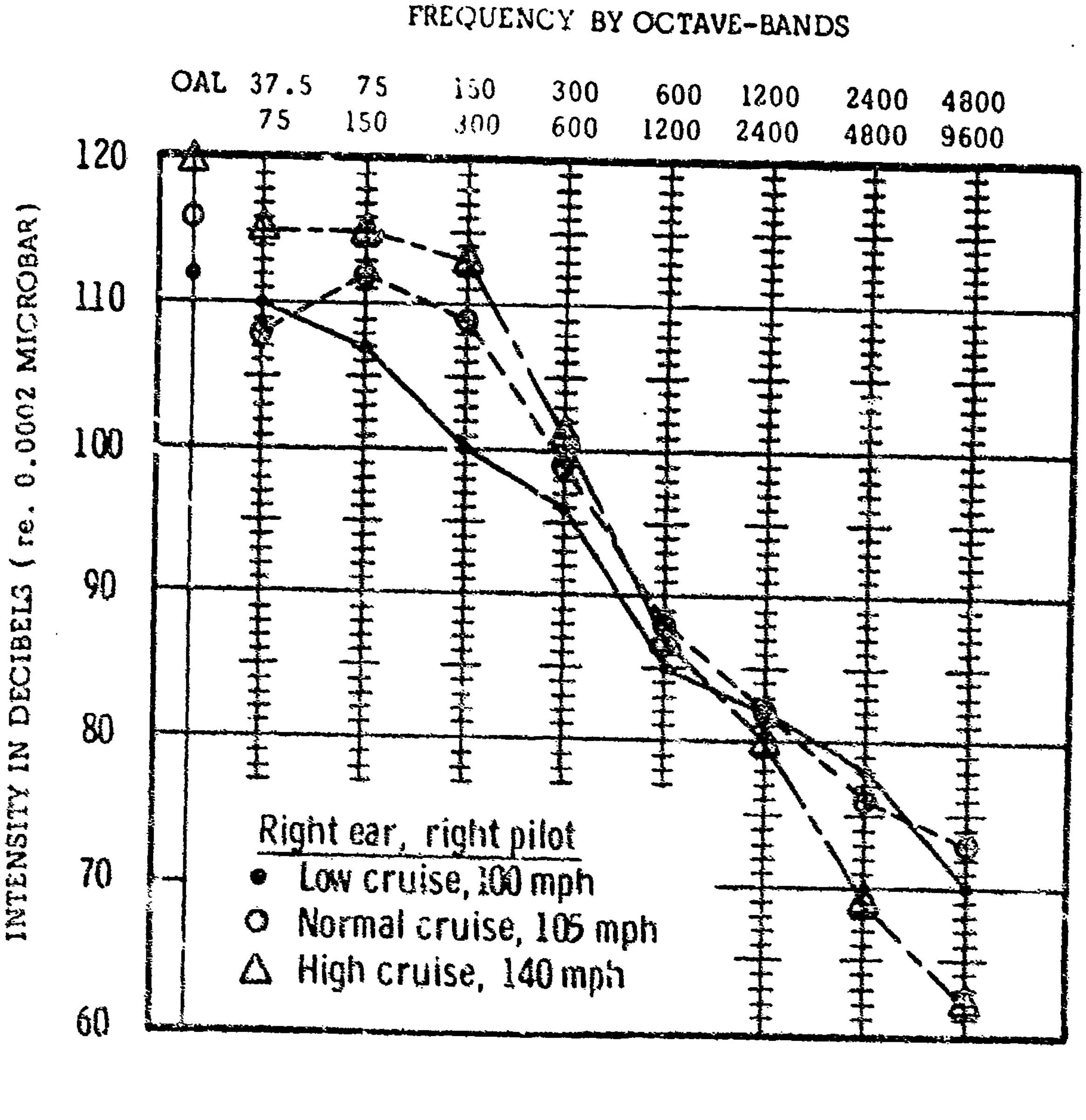

Fig. 66 Internal Noise of U-6A Aircraft During Low, Normal, and Maximum Cruise at 5500' Altitude

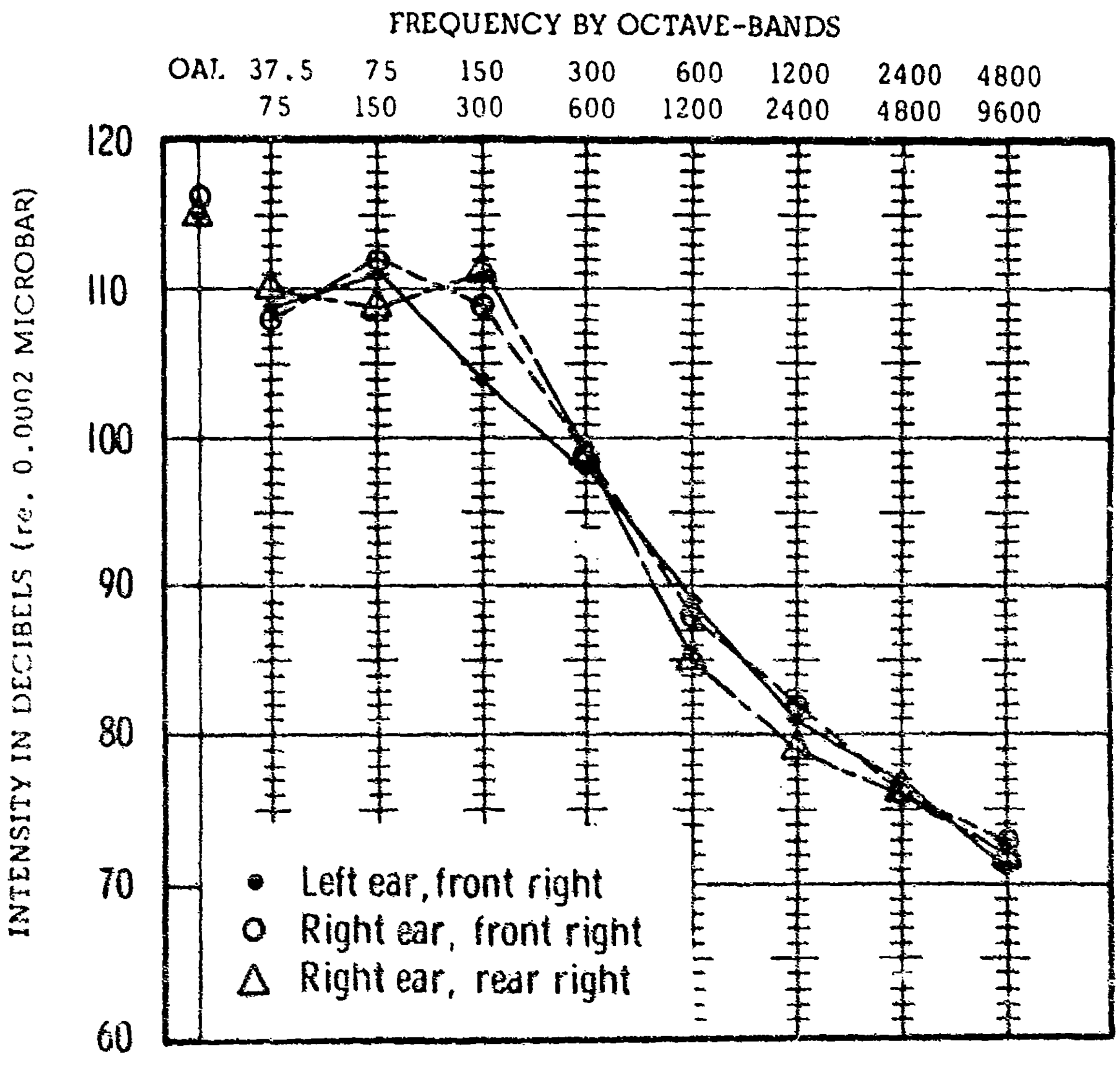

Fig. 67 Internal Noise of U-6A Aircraft During Normal Cruise at 5500' Altitude, 1800 RPM, 28" MP, 105 Knots IAS

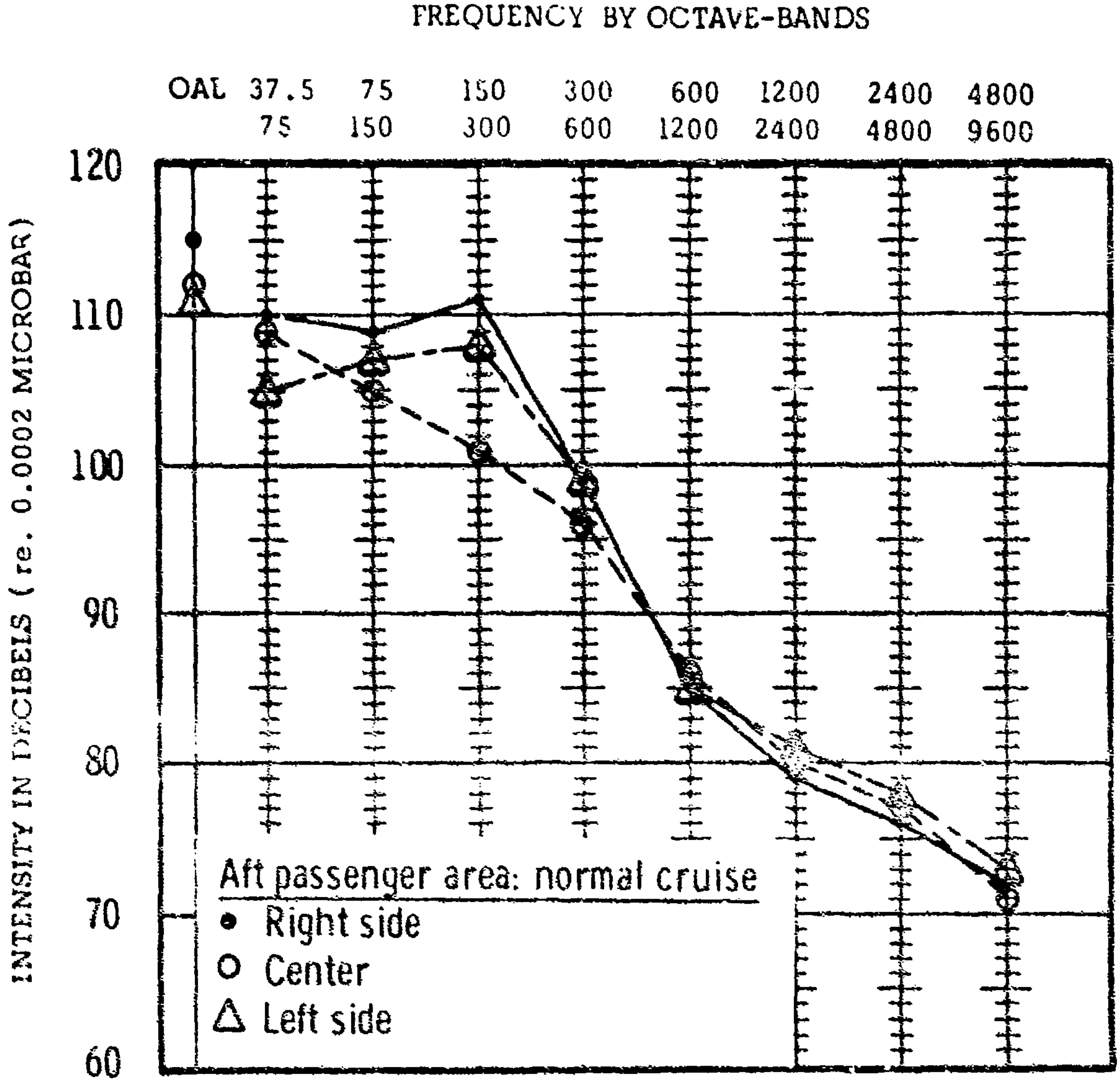

Fig. 68 Internal Noise of U-6A Aircraft During Normal Cruise at 5500' Altitude, 1800 RPM, 28" MP, 105 Knots IAS

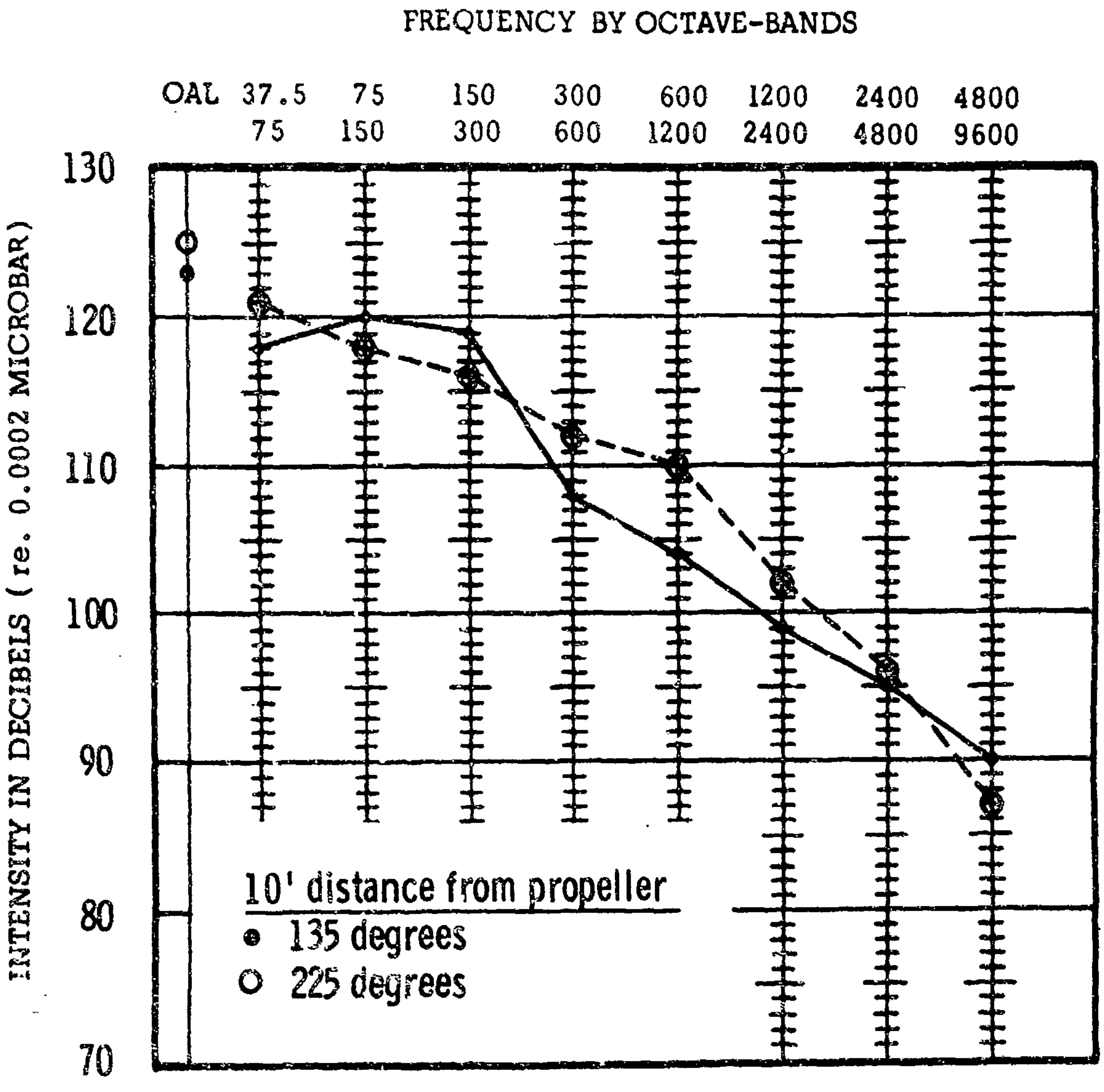

Fig. 69 External Noise of U-6A Aircraft During Ground Operations, Measured at 10' Distance, 1750 RPM

U-8D, F.

The U-8D and U-8F aircraft are powered by essentially the same engines and propeller systems. The primary difference between the two models is the passenger-cargo capability. The U-8D and U-8F are powered by two Lycoming 0-480 in-line reciprocating type engines which operate at approximately 340 brake horsepower at 3,400 rpm at take-off and produce about 320 brake horsepower at 3,200 rpm during normal high rated continuous power. Both aircraft are fitted with a three-blade propeller that has a diameter of 7'9".

Internal Noise: The internal noise levels are basically the same between the two models, except that the pilot compartment of the U-8F is in closer proximity with the propeller plane. The exhaust ports for both models are located on the lower sides of the engine nacelles and dump the exhaust gases beneath the wing. Because of this the noise emanating from the exhaust is partially occluded (or blocked) by the wing and, therefore, does not significantly invade occupied areas within the main fuselage.

Figure 70, page 100, shows results of noise measurements taken within a U-8D during normal cruise. During these measurements the aircraft was flying at an altitude of 4,000 feet and an airspeed of 150 knots (IAS). The engines were operating at 2,600 rpm, which constitutes a normal engine power operation of about 60 per cent of maximum power. The noise measurements indicate the presence of some aerodynamic noise generated near the front left window (the forward section of which can be opened or closed but is normally opened only during ground operations). Figure 71, page 101, depicts noise measurements taken at a position between the pilots during climb. The measurements show only slight differences in the level of the over-all noise as the aircraft climbs from 500 through 2,800 feet. During climb the engines were operating at 3,000 rpm and 40 inches of manifold pressure. Although the noise is rather intense, the duration of exposure is not considered excessive because once desired altitude has been achieved the power on the engines is reduced. Figure 72, page 102, shows a comparison of the noise exposure existing at the right and left pilot positions in the U-8D aircraft during normal cruise. These measurements were completed while the engines were operating at 2,600 rpm and 32 inches of manifold pressure. The aircraft maintained an airspeed of 150 knots (IAS) and an altitude of 4,000 feet. The results of these measurements show the added influence of aerodynamic noise produced by the passage of the slipstream over the seals of the door which is located on the right side of the fuselage.

Noise plottings in Figure 73, page 103, demonstrate the relative distribution of the noise within a U-8F during normal cruise. These plottings show differences in over-all noise levels as well as differences in the spectrum of the noise,

especially at frequencies below 150 cps. Noise emanating from the propellers is most intense at the forward location within the pilot compartment. The level of the propeller noise becomes progressively less intense as one moves farther aft in the passenger-cargo compartment. In the extreme aft section of the passenger-cargo compartment, the presence of exhaust noise is noticeable primarily because in these positions there is significantly less acoustical treatment than at forward locations.

Figure 74, page 104, shows results of noise measurements taken in the center position between the pilots during take-off and normal cruise. Increases in engine rpm and manifold pressure account for the intense noise levels generated in the 75 to 150 cps frequency range. Then during normal cruise the spectrum distribution of the noise remains relatively the same but becomes less intense. Noise emanating from the propellers during take-off produce intense noise in the 75 to 150 cps octave band. During normal cruise (with the engines at lower rpm) the higher frequency components are less intense and the fundamental tends to increase, resulting in a closer proximity of distribution of the noise in frequency ranges below 150 cps.

Noise produced by exhaust and structural resonances are illustrated in the noise plottings of Figure 75, page 105. These measurements were completed in the aft sections of the passenger-cargo compartment in a U-8F during normal cruise. These noise levels are representative of the characteristically low frequency noise generated by the acoustical components of both exhaust and propellers.

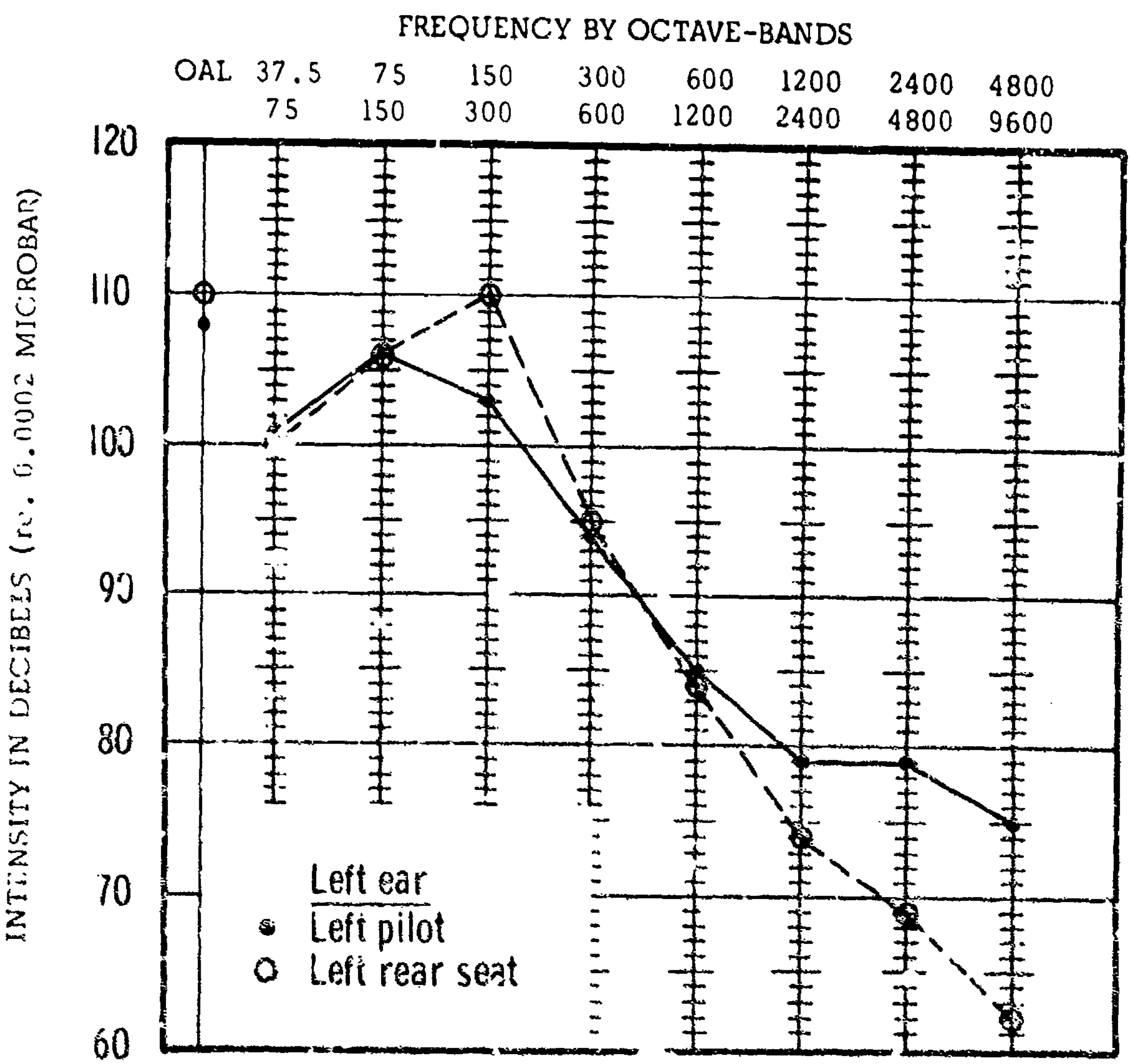

Fig. 70 Internal Noise of U-8D Aircraft During Normal Cruise at 4000' Altitude, 2600 RPM, 32" MP, 150 Knots IAS

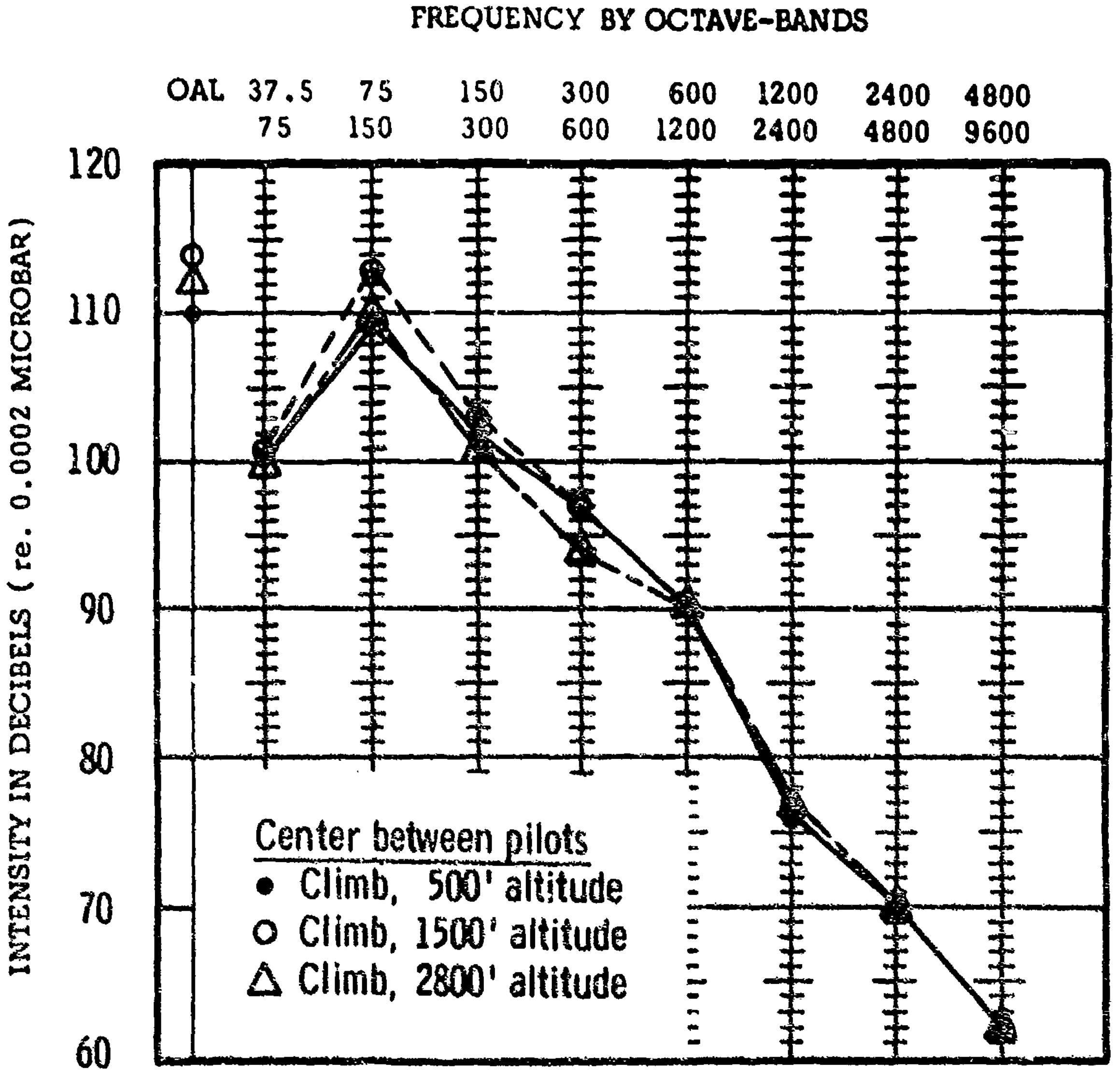

Fig. 71 Internal Noise of U-8D Aircraft During Climb, 3000 RPM, 40" MP, 120 Knots IAS

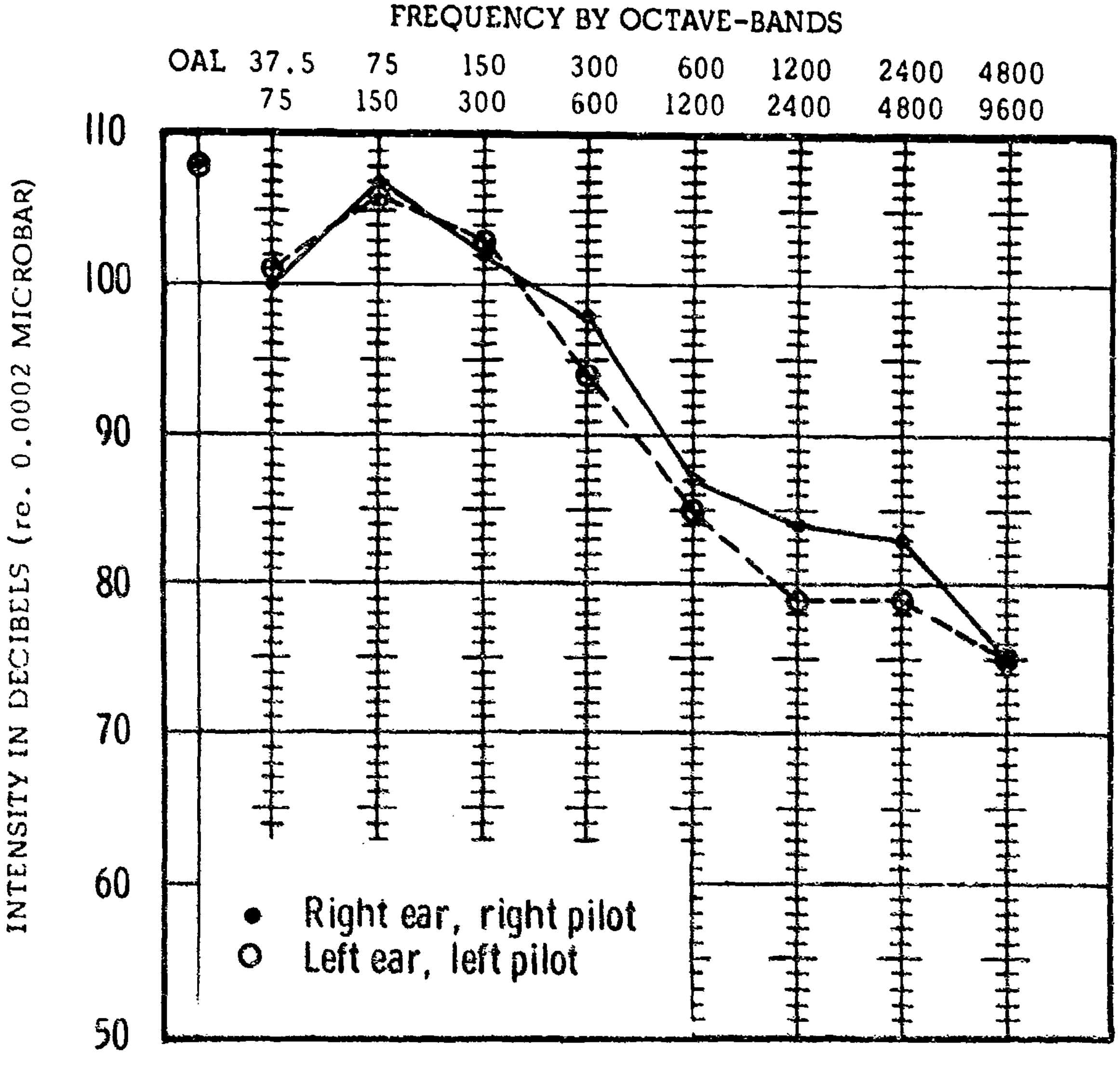

Fig. 72 Internal Noise of U-8D Aircraft During Normal Cruise at 4000' Altitude, 2600 RPM, 32" MP, 150 Knots IAS

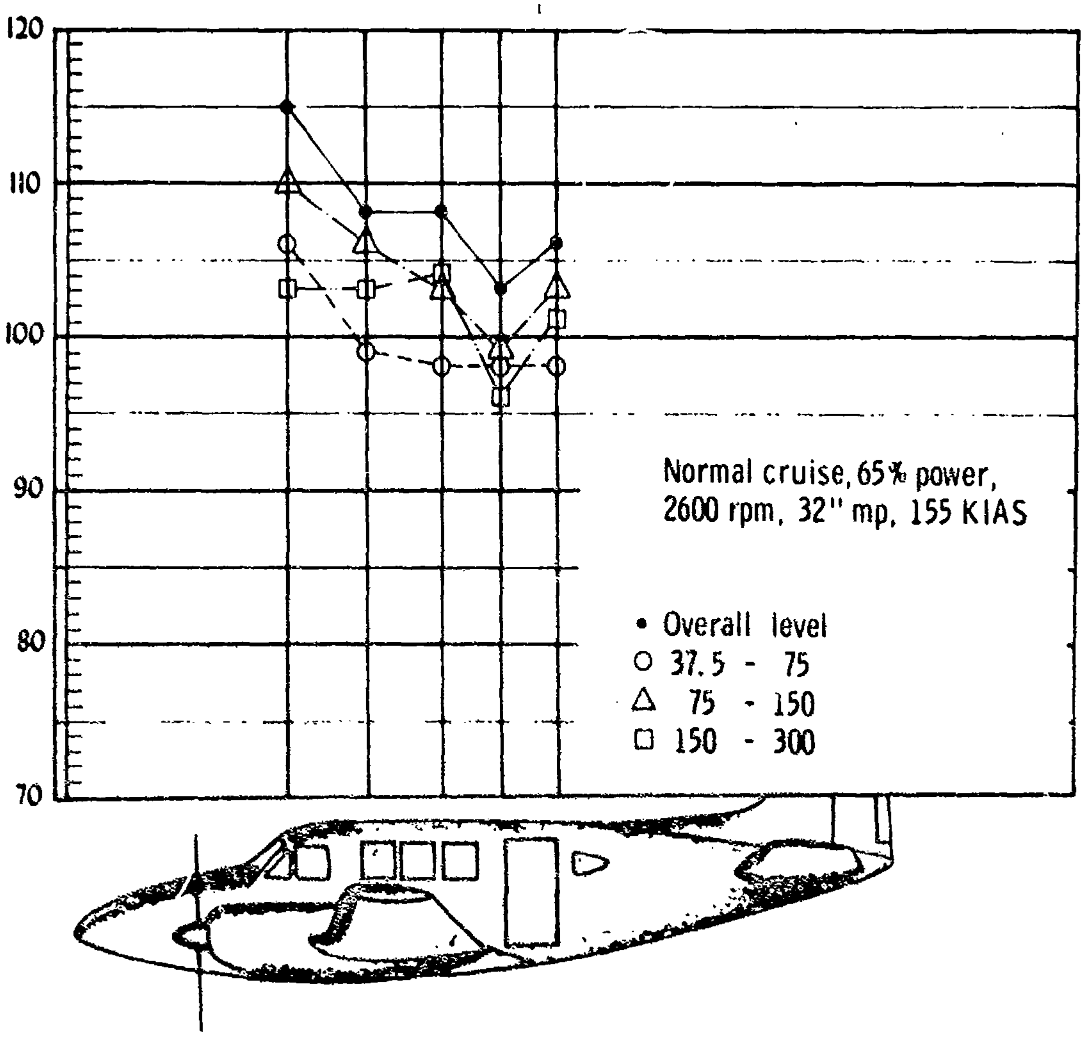

Fig. 73 Internal Noise of U-8F Aircraft During Noimal Cruise at 5000' Altitude, 65%, 2600 RPM, 32" MP, 155 Knots IAS

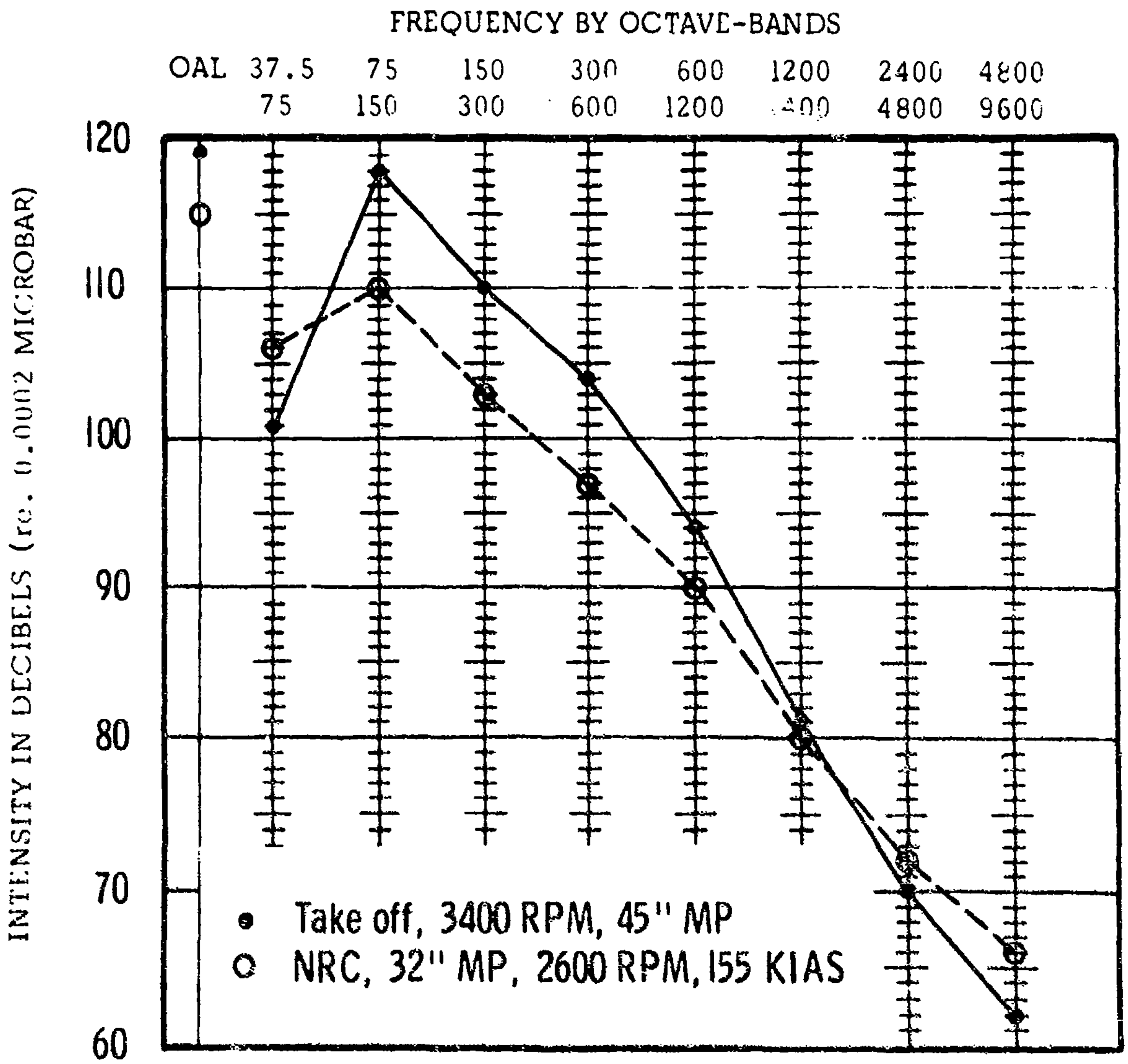

Fig. 74 Internal Noise of U-8F Aircraft During Take-Off and Normal Cruise

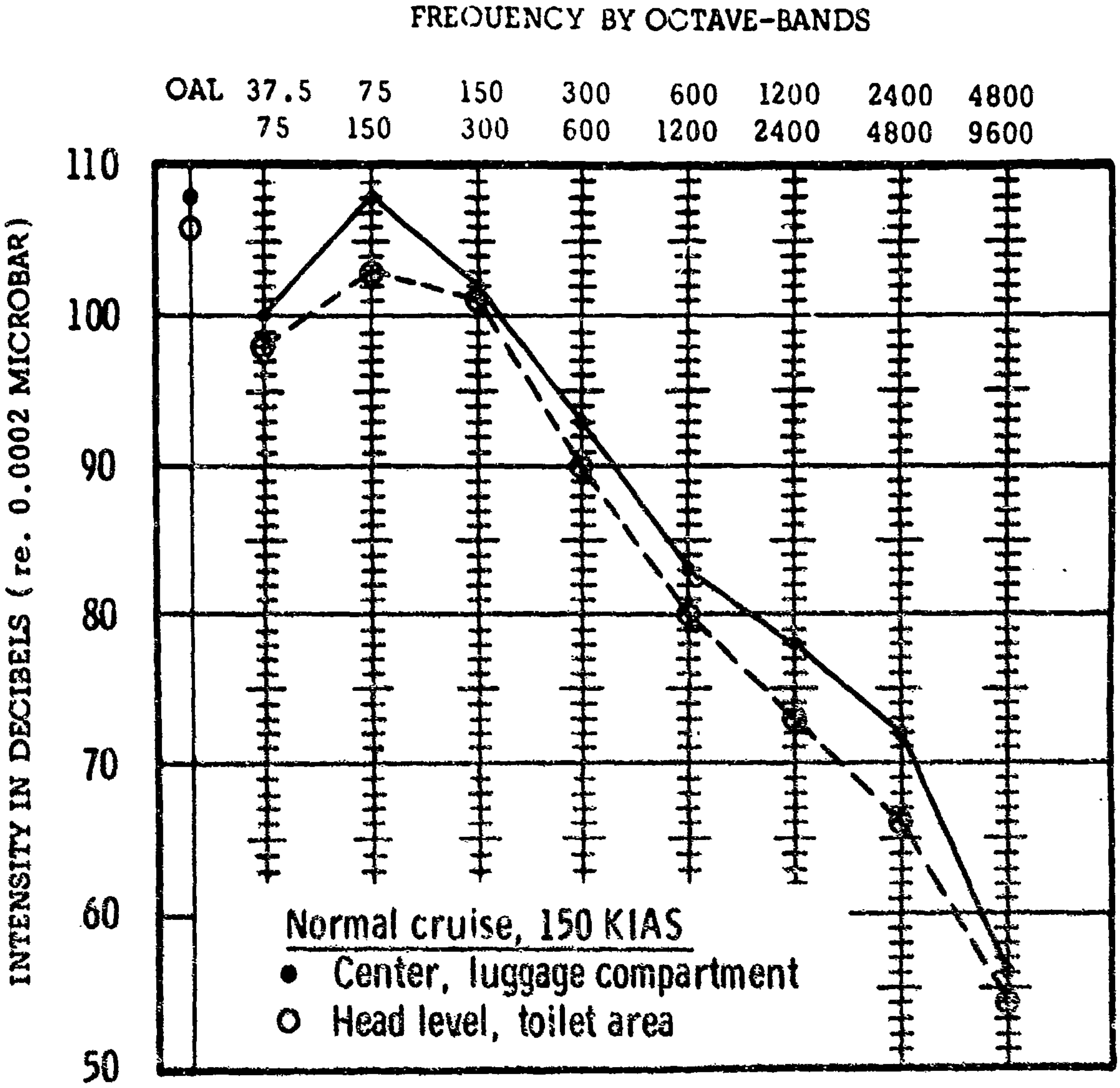

Fig. 75 Internal Noise of U-8F Aircraft During Normal Cruise at 3000' Altitude, 2600 RPM, 32" MP

U-9B.

The U-9B is a twin-engined aircraft that is powered by two Lycoming GO-435 in-line reciprocating engines and is fitted with three-blade propellers. The engines can generate approximately 255 brake horsepower at 3,400 rpm during take-off. The forward compartment area houses the pilots and the aft compartment area provides room for passengers or cargo. The propeller plane is located just aft of the pilot seat position. The high wing allows some of the exhaust noise from the engines to invade the internal aft compartment area. However, since the exhaust is ported outboard, the amount of exhaust noise intruding into the aft compartment area is not excessive.

Internal Noise: Figure 76, page 107, shows plottings of noise measurements completed at the left ear of the left pilot during both normal cruise and climb. During climb the blade pitch of the propeller blades is less and the propellers rotate at a high rpm, thus producing noise which peaks at 75 to 150 cps. At normal cruise, although the rpm is reduced, the pitch of the propeller blades is increased (greater angle of "bite"), thus producing a noise which is relatively flatter throughout the frequency range from 75 through 300 cps. The noise levels shown in Figure 77, page 108, are representative of noise measurements taken at locations near the left entrance door and the escape hatch which is located on the right side of the fuselage directly across from the entrance. These noise levels are essentially the same except that the levels measured near the entrance are illustrative of a greater amount of noise generated by slipstream disturbances.

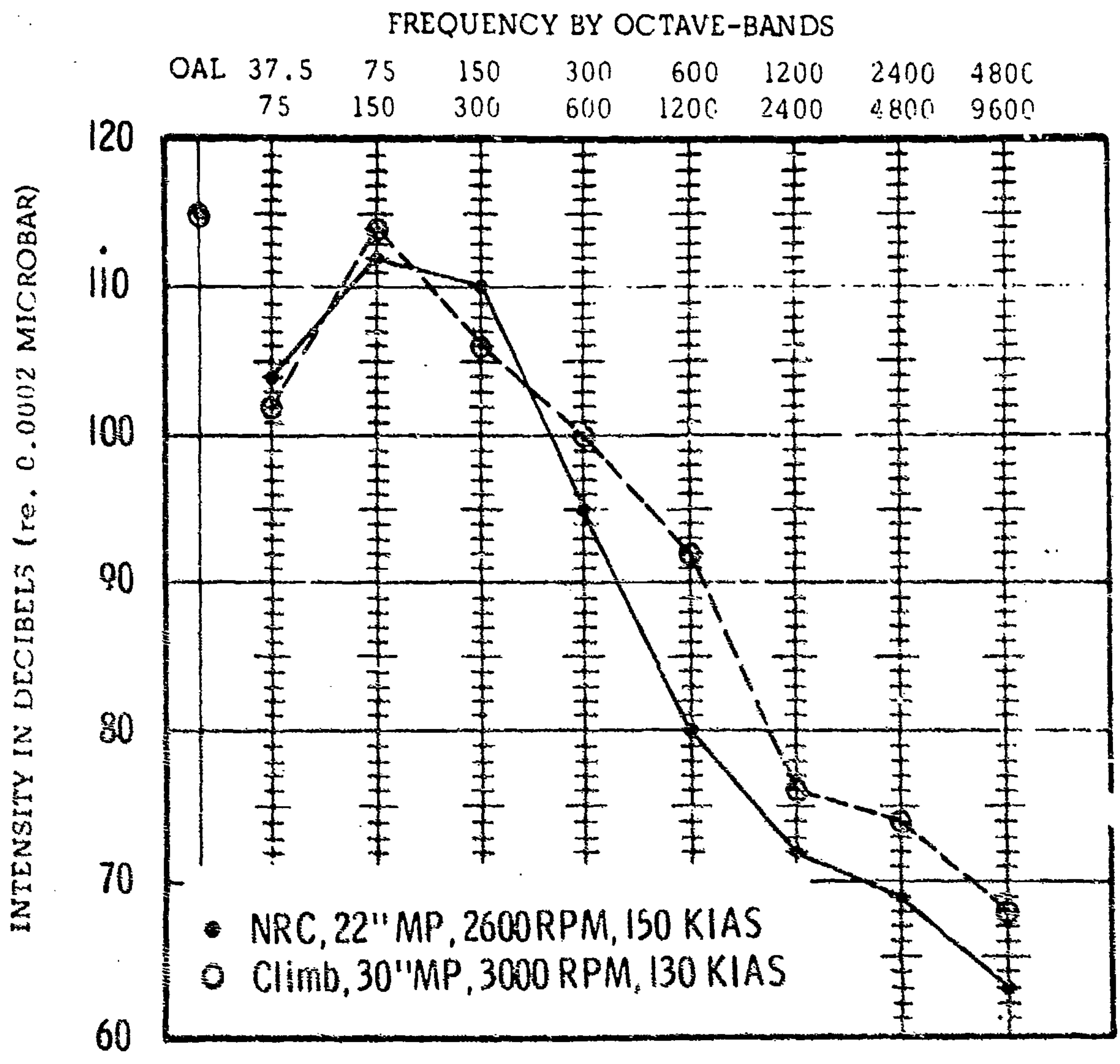

Fig. 76 Internal Noise of U-9B Aircraft During Climb and Normal Cruise

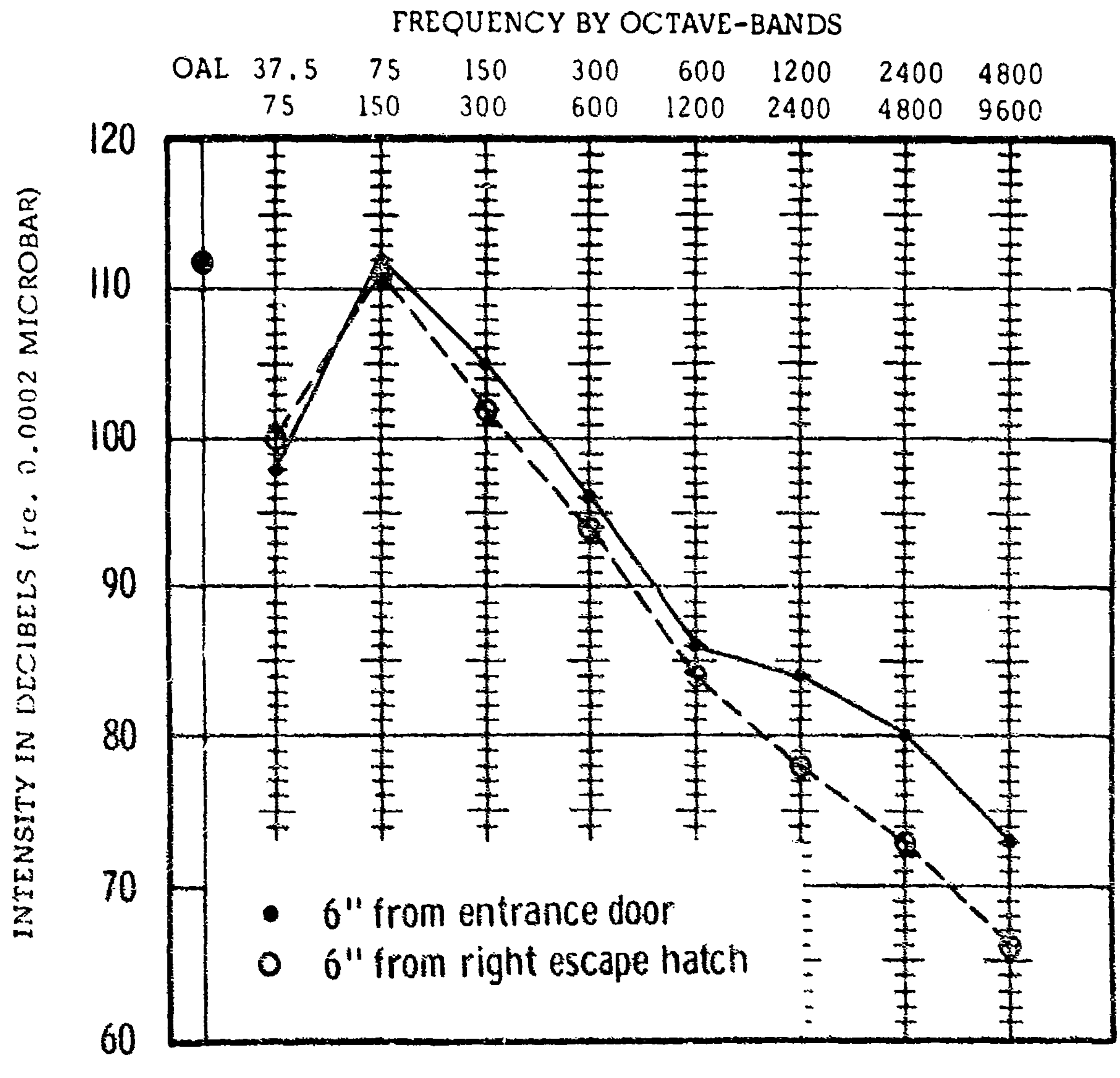

Fig. 77 Internal Noise of U-9B Aircraft During Normal Cruise at 2700' Altitude, 2600 RPM, 22" MP, 150 Knots IAS

B. Short Take-Off and Landing Aircraft (STOL)

OV-1A, B.

The OV-1A and OV-1B is a two-place, twin-engined, turboprop aircraft. The aircraft is powered by Lycoming T53-L-3 or T53-L-7 turboprop engines, each producing 1,005 equivalent shaft horsepower. These aircraft are fitted with two three-blade Hamilton Standard propellers having a diameter of ten feet. The mating of turboprop power plants to this aircraft provides outstanding short field take-off and landing capability. The propellers are reversible and allow very good braking during reversed thrust landing operations. Achievement of the most efficient braking action during landing is obtained by applying the maximum allowable propeller shaft torque during initial landing roll, thus the level of the noise generated by the propellers during this maneuver is rather intense but lasts only for a short period of time. Actually, intense noise levels generated during this maneuver last approximately two to six seconds.

Internal Noise: Figure 78, page 112, shows plottings of the noise generated at the right ear of the occupant in the right seat of an OV-1A during operation of the gas-turbine engines only. During these measurements the noise was produced almost exclusively by the compressor and turbine stages of the engine (propellers were not operating). The noise was measured with the side entrance windows locked in the PARTIALLY OPEN position (open at the bottom approximately eight to twelve inches). As noted, the noise generated by the engines is not excessively intense at internal positions, and the peak noise level is found in the 2400 to 4800 and 4800 to 9600 cps octave bands. Since the aviator wears an APH-5 helmet, this noise is not annoying or damaging because the noise attenuation offered by the earphone cushions within the helmet offer adequate noise protection. The noise levels recorded in Figure 79, page 113, illustrate noise exposures generated at the same position within the aircraft during various ground run-up operations. The noise exposures represent the amount of noise received at head level by the occupant on the right side of the cockpit during two phases of ground run-up: propeller check and engine power checkout. During propeller check the engine provides the required propeller shaft rpm to check the propeller during rotation, and during power check the propeller is brought to a high rpm and high pitch is applied to the propeller blades. The noise is found to be most intense during the power check phase when the propellers are placed in high pitch. The increased noise levels experienced during the power check maneuver results primarily from the high torque applied to the blades of the propellers. The noise generated by the propellers during propeller check (first plotting) is distributed primarily in the very low frequency ranges. During propeller check the propellers had a fundamental blade passage frequency of 70 times per second and a blade tip velocity of 733.1 feet per second. At 1,650 rpm the propeller had a fundamental blade

passage frequency of approximately 82.5 times per second with a blade tip velocity of 864.5 feet per second. The noise generated by the right engine propeller is naturally more intense than the noise produced by the left propeller during the same power operation because the right propeller is closer to the occupant in the right seat where the measurements were recorded.

Figure 80, page 114, shows results of noise measurements taken at the right ear of the occupant in the right seat during various phases of flight. During maximum cruise the most intense single element of noise is that emanating from the propellers, being most evident in the frequency range below 150 cps. At normal cruise the propellers still contribute the most intense noise levels recorded within the cockpit. During letdown at high airspeed and the engines at low power, the spectrum of the internal noise shows the influence of aerodynamic disturbances created by the passage of airflow over and around the cockpit area. Noise due to this phenomenon is most pronounced at frequencies above 600 cps.

Figure 81, page 115, shows results of noise measurements taken at different positions within an OV-1A during maximum cruise. These measurements were completed while the aircraft was flying at an altitude of 2,500 feet (nonpressurized) and an airspeed of 200 knots (IAS). The engines were operating at 91 per cent rpm, the propeller was rotating at 1,600 rpm, and each engine was producing 60 psi of torque.

In general, the noise levels generated within the cockpit of the aircraft during most operations are directly determined by the operation of the propellers of the aircraft. The internal noise is rather high during various phases of powered flight as well as during ground run-up and engine checkout prior to take-off. In many instances, the entrance ports on the sides of the cockpit are left in a partially open position during ground run-up and engine checkout operations. The noise levels produced by the propellers and the compressor stages of the engines would be somewhat less intense if the side canopies were closed during these operations. Thus, if at all possible, these cockpit windows should be left closed during engine and propeller run-up. During low powered flight operations differences in rpm synchronization between the propellers may cause noticeable "beats." This phenomenon is most noticeable when the engine is operating at low rpm and high blade pitch.

<u>External Noise</u>: Figure 82, page 116, illustrates the type of noise exposures produced at various external locations near an OV-1B aircraft during power check of one engine. The noise measurements were completed while the engine was operating at 97 per cent rpm which produced a propeller speed of 1,678 rpm. These measurements were taken at a distance of 50 feet from the nose wheel of the aircraft. At 1,678 rpm the propeller produced its most intense noise at a location in the

propeller plane (90 degrees). At a position behind the propeller plane, 135 degrees, rotational noise components associated with the propeller are evident. Figure 83, page 117, shows results of noise measurements taken at the same positions and distances during the propeller check. The propeller had a rotational speed of 1,150 rpm and the engine was operating at approximately 83 per cent rpm. Although the over-all noise is considerably less intense during this operation, the frequency spectrum is more evenly distributed throughout the frequency range.

The influence of blade pitch on the noise produced at a location almost in-line with the propeller (90 degrees) is shown in Figure 84, page 118. As the propeller pitch is changed from low to high, the amount of noise produced in the frequency range below 300 cps is significantly altered. During high pitch the amount of acoustical energy generated in the lower frequencies is significantly increased and there is very slight, if any, difference in the distribution of noise within the higher frequency ranges. In Figure 85, page 119, measurements were taken at 135 degrees and the influence of increased blade pitch on the propeller noise is more noticeable than at a location within the propeller plane. The increased noise due to increased propeller pitch (and torque) is most evident in the frequency range below 600 cps.

The noise generated by OV-1A and OV-1B aircraft during normal ground operations is essentially the same from one aircraft to another during similar operational maneuvers. During high power operations, the intense noise produced by the propellers of the Mohawk aircraft tends to mask the less intense noise generated by the jet exhaust. At maximum power, the T53 engine of the OV-1A and OV-1B will produce only about 125 pounds of thrust and the extreme air turbulence generated behind the engine by the propellers tends to increase the turbulent mixing of the exhaust gases, thus creating a natural reduction in jet exhaust type noise.

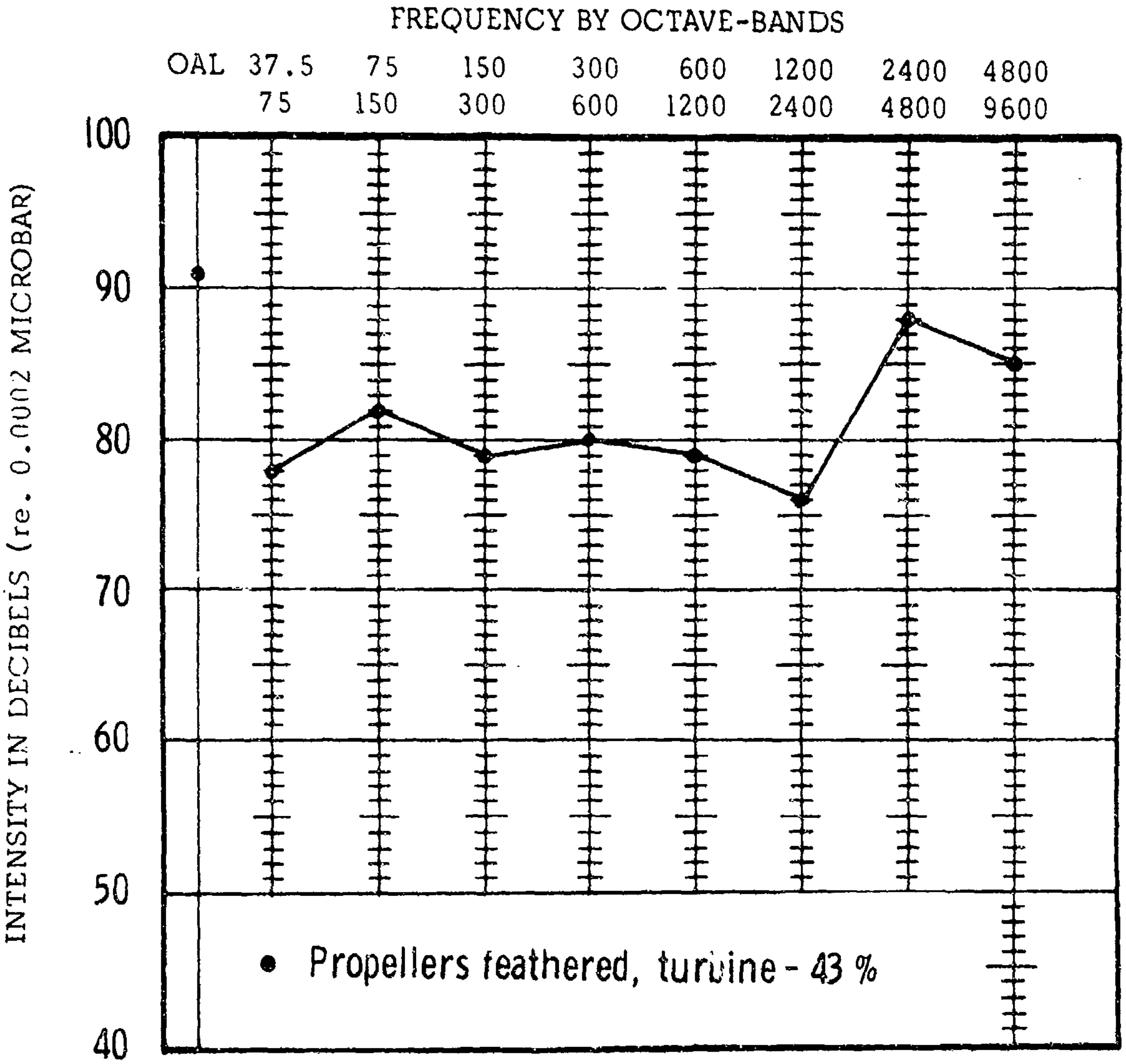

Fig. 78 Internal Noise of OV-1A Aircraft During Ground Operations, Propellers Feathered

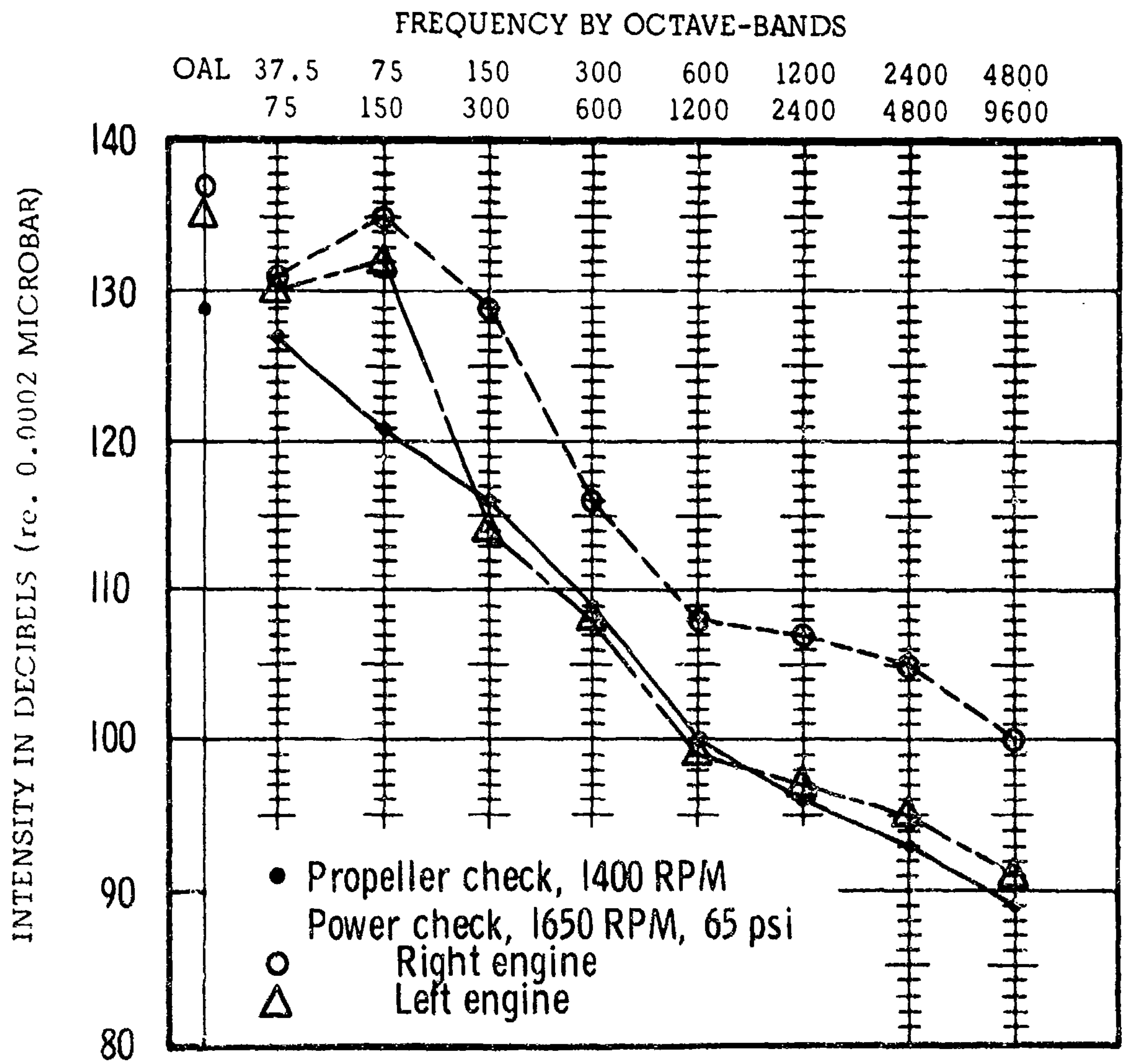

Fig. 79 Internal Noise of OV-1A Aircraft During Ground Operations, Power versus Propeller Check

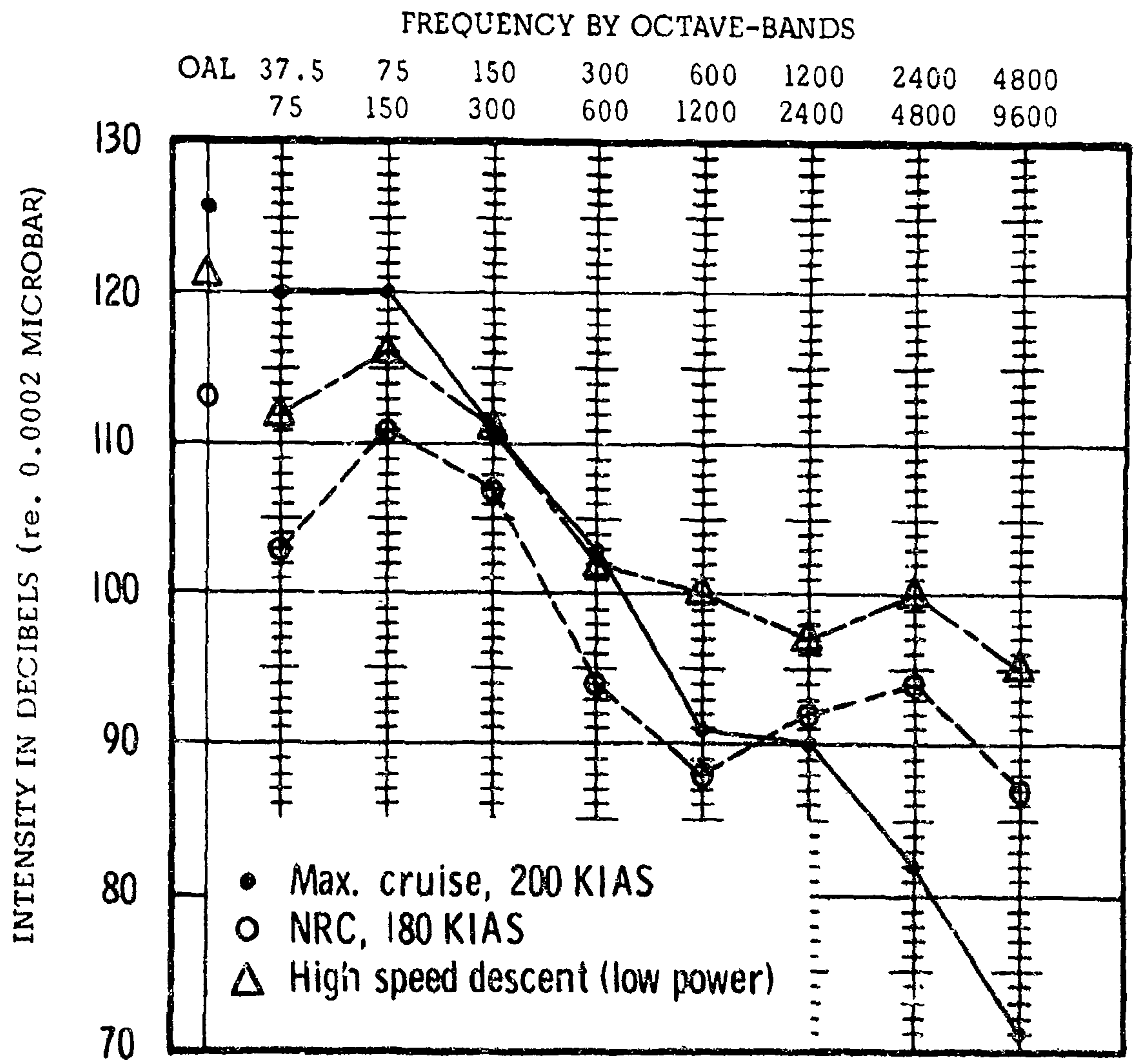

Fig. 80 Internal Noise of OV-1A Aircraft During Normal Cruise, Maximum Cruise, and High Speed Descent

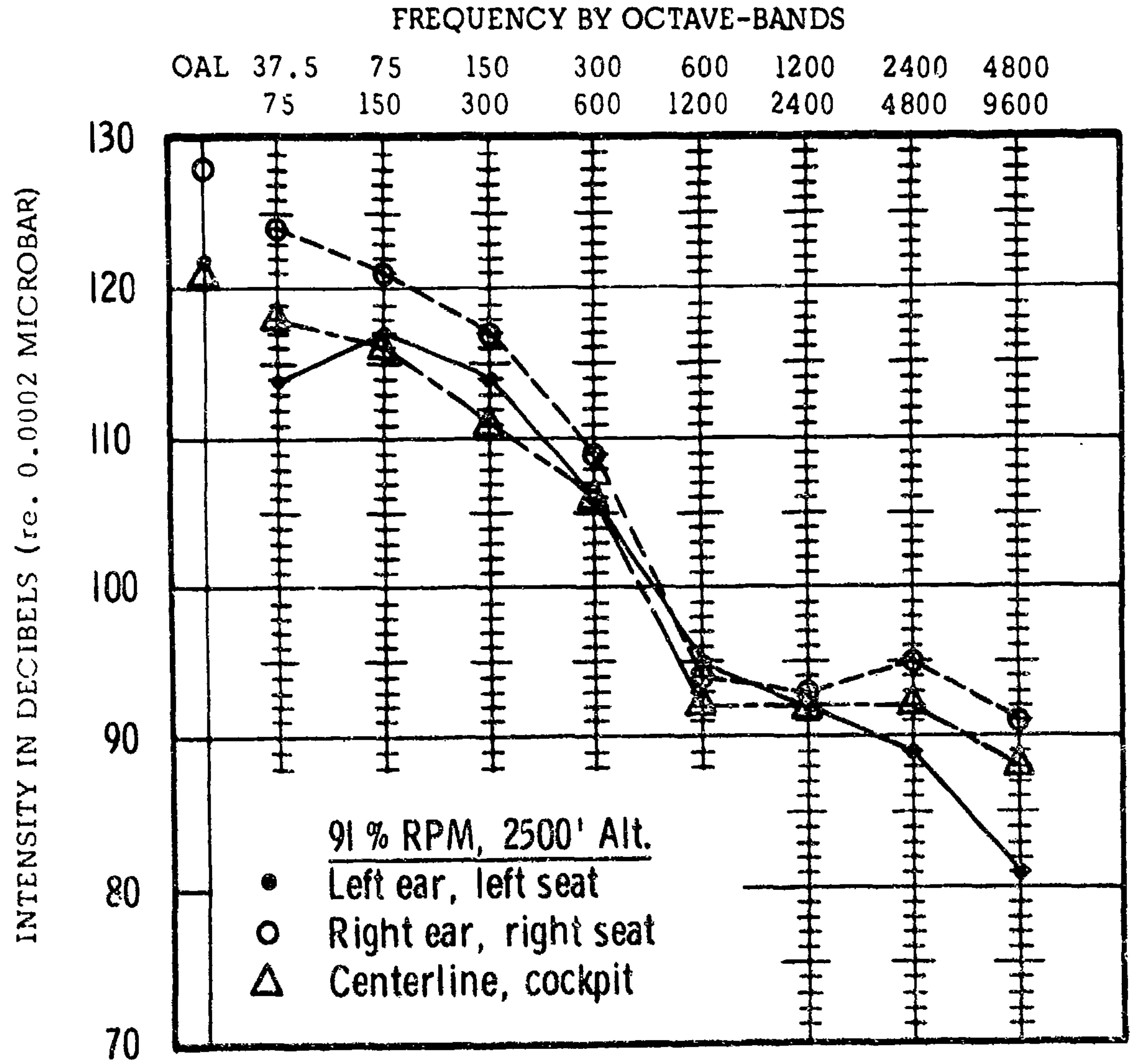

Fig. 81 Internal Noise of OV-1A Aircraft During Maximum Cruise at 2500' Altitude, 1600 RPM, 60 PSI Torque, 200 Knots IAS

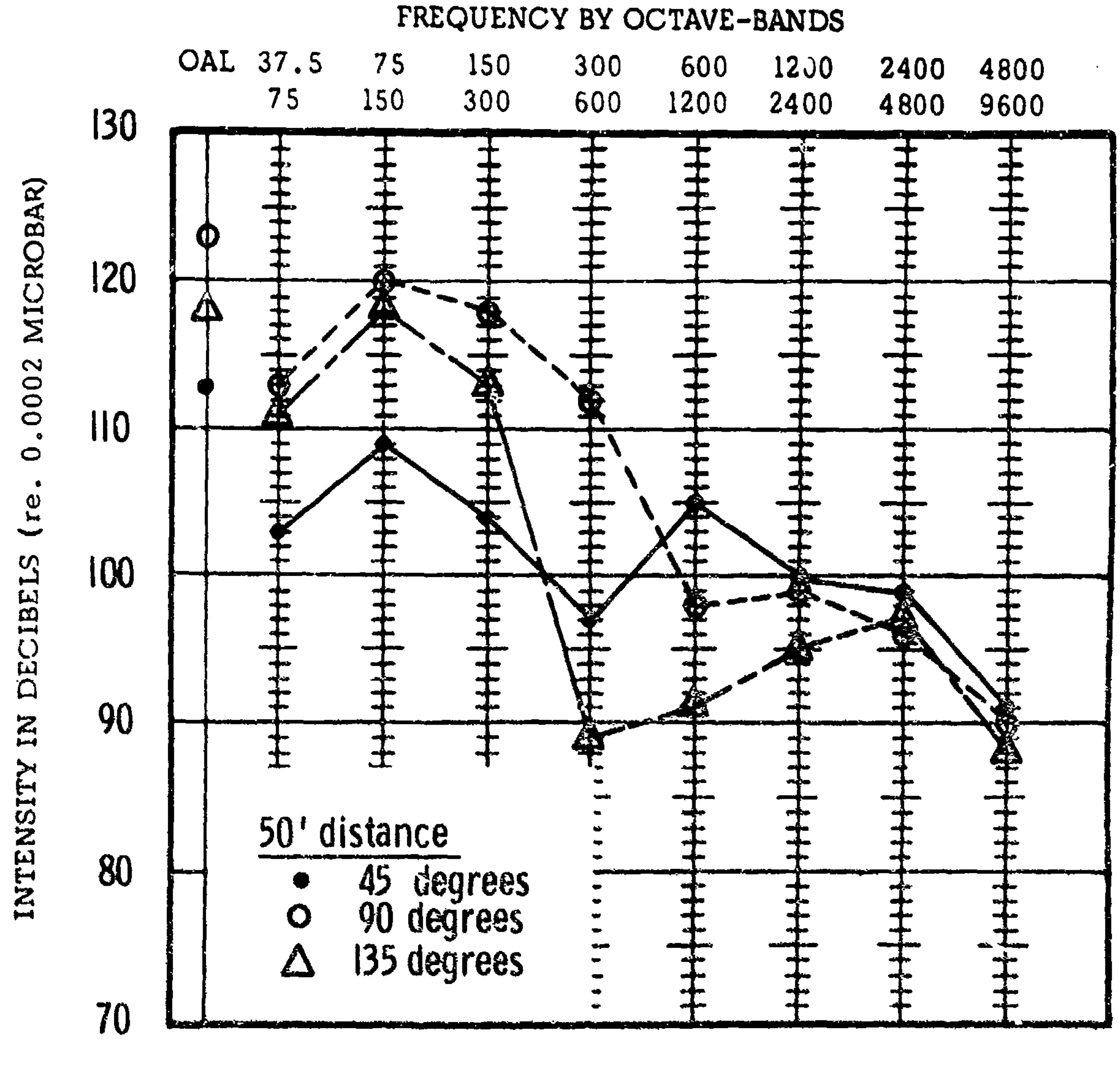

Fig. 82 External Noise of OV-1B Aircraft During Ground Power Check, 97%, 1678 RPM

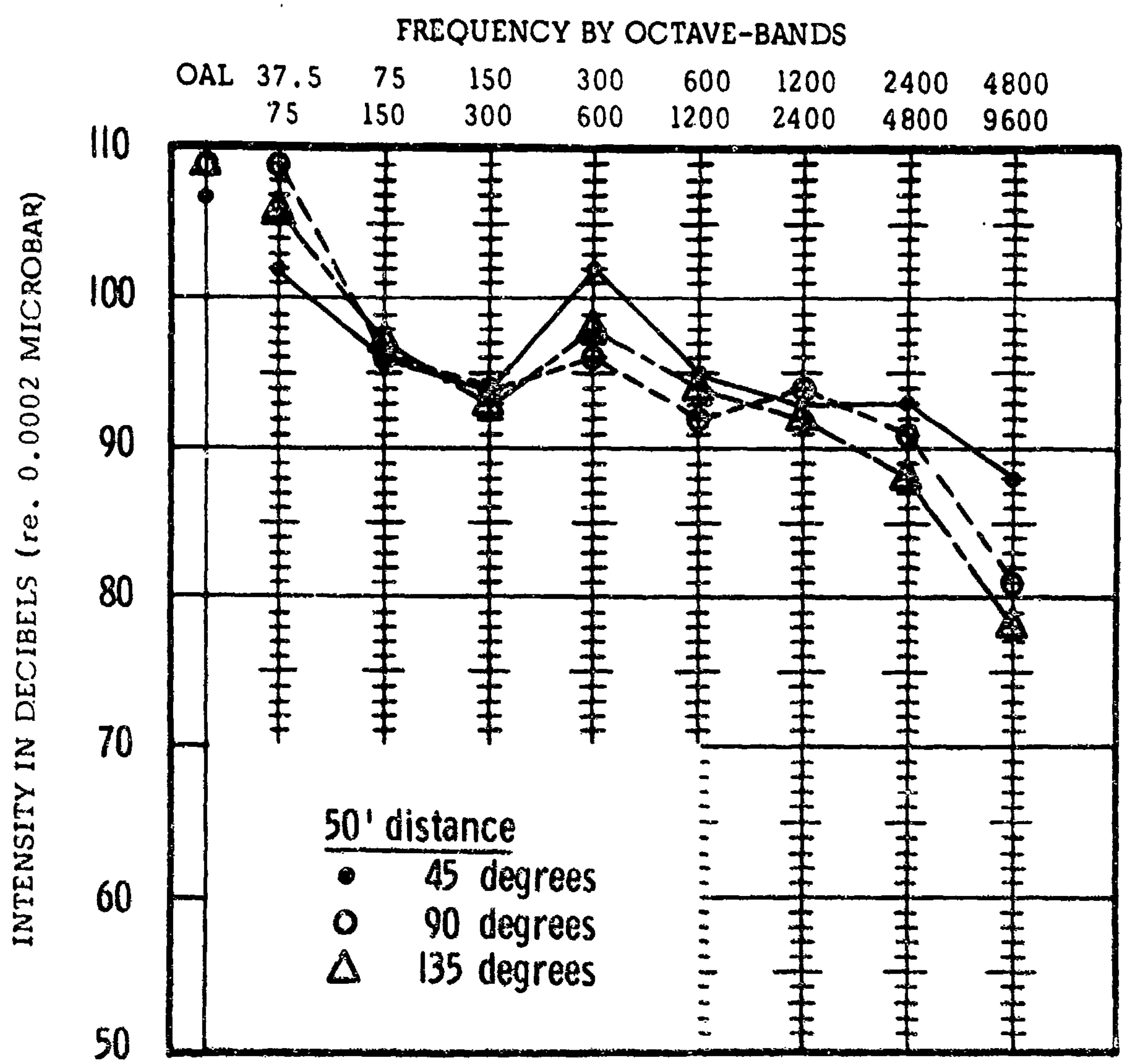

Fig. 83 External Noise of OV-1B Aircraft During Ground Propeller Check, 83%, 1150 RPM

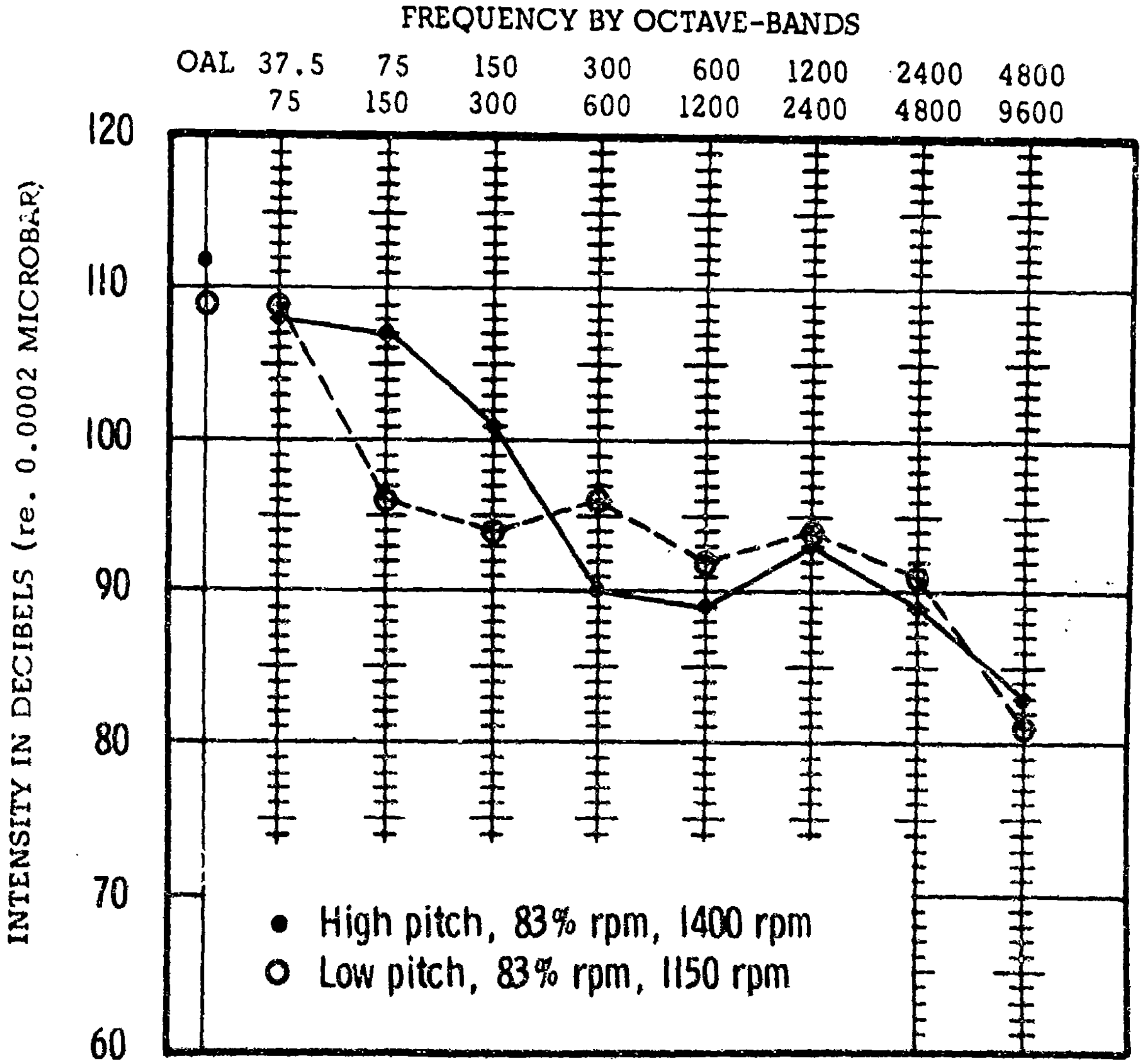

Fig. 84 External Noise of OV-1B Aircraft During Ground Propeller Check, Low versus High Pitch, Measured at 50' Distance

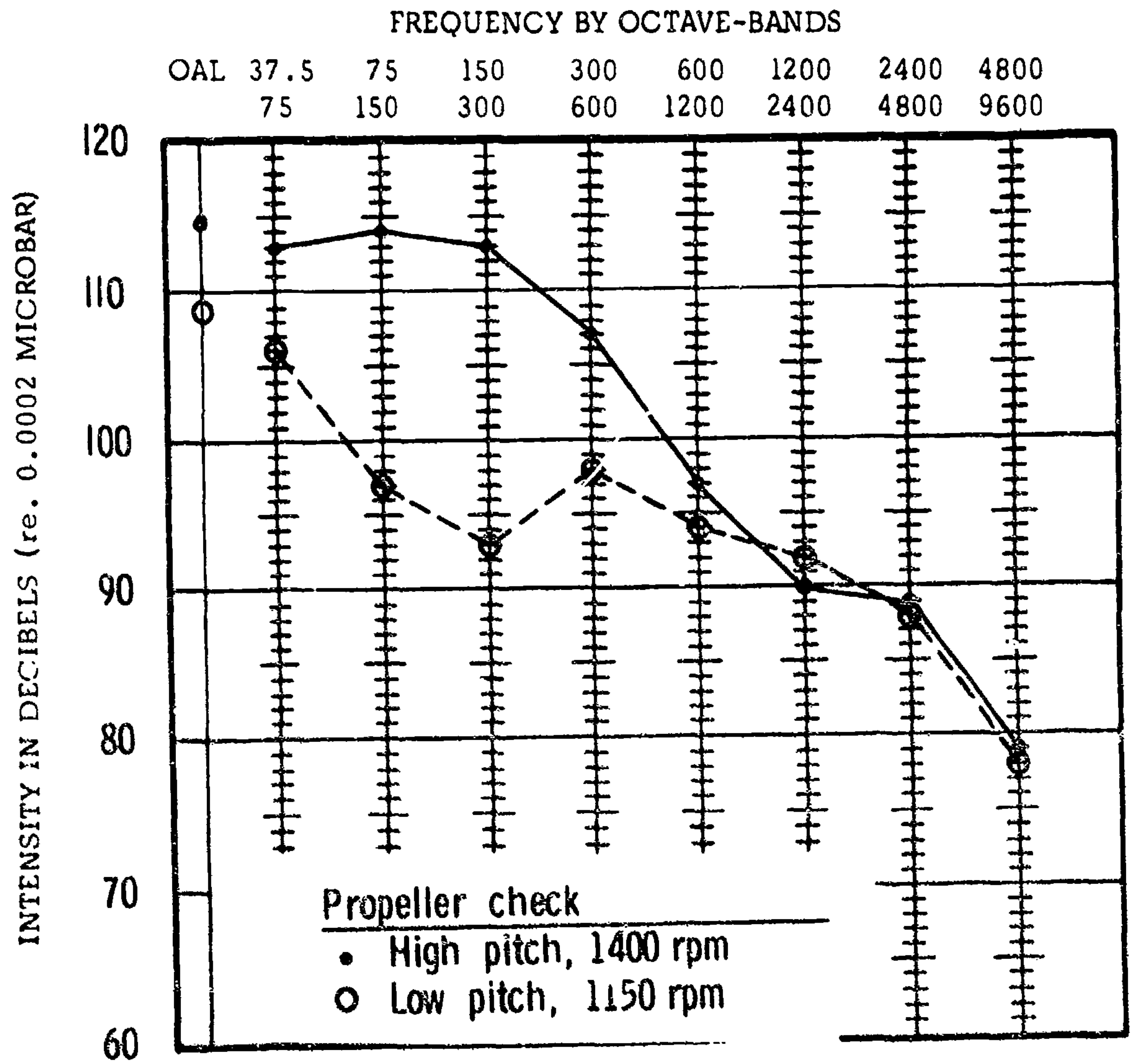

Fig. 85 External Noise of OV-1B Aircraft During Ground Propeller Check, Directivity Pattern

CV-2B.

The CV-2B is a conventional, twin-engined, cantilever high wing aircraft. The aircraft is powered by two Pratt and Whitney R2000 radial type reciprocating engines capable of producing 1,450 brake horsepower at 2,700 rpm at maximum take-off power and approximately 1,200 brake horsepower at 2,550 rpm at METO power. The aircraft has two three-blade Hamilton Standard propellers, each having a diameter of 13'1". Each engine is fitted with dual exhaust augmentor tubes that are located directly behind the engine nacelle and expel the exhaust gases from the engine at a location just above the trailing edge of the main wing area. Since the aircraft has a high wing, considerable blockage of the exhaust noise exists because the wing is between the exhaust ports and normally occupied positions within the aircraft.

Internal Noise: Figure 86, page 123, shows plottings of noise measured within a CV-2B at various internal locations during normal cruise. These measurements were completed while the aircraft was operating at 2,000 rpm and 32 inches of manifold pressure. The aircraft was flying at an altitude of 5,500 feet and at an airspeed of 140 knots (IAS). The noise measurements were plotted for the over-all noise levels as well as for levels generated within the 37.5 to 75, 75 to 150, and 150 to 300 cps frequency ranges. The noise measured in aft locations is representative of two primary noise factors: 1) Noise emerging from the exhausts of the engines at normal cruise causes a slight increase in the levels measured in the aft sections of the fuselage. Noise levels in the 150 to 300 cps octave band are due to the exhaust and, as noted from the noise plottings, are most pronounced at aft locations in the main passenger-cargo compartment. 2) Noise produced by the propellers is most evident within the 37.5 to 75 cps octave band and is most intense at locations near the propeller plane, whereas the exhaust noise, dominant in the 150 to 300 cps band, is most evident in the extreme aft sections. In fact, the noise generated by the propellers is the most significant single noise component since it primarily determines the magnitude of the over-all noise levels recorded at locations near the propeller plane. The noise produced by the exhaust is the most significant noise component that determines the magnitude of the over-all noise present in the aft sections of the fuselage. The aft section of the main fuselage does not have as much acoustical treatment as the forward section of the cargo area, thereby allowing intrusion of much of the externally generated noise. Figure 87, page 124, shows the relative influence of center versus side locations at various internal positions within the fuselage of the CV-2B during normal cruise. Noise generated at locations forward of the main wing in the center line of the cargo compartment is less intense than noise generated at similar locations at the side of the fuselage. At positions aft of the leading edges of the wing, the noise levels are basically the same.

Figure 88, page 125, shows plottings of noise levels recorded within the propeller plane (head level at troop seat locations) during various phases of powered flight. During three phases of flight - take-off, METO climb, and normal cruise - the propellers are the major noise producing mechanisms. During take-off the propellers had a blade passage frequency of 67.5 times per second and a blade tip velocity of 926.0 feet per second (0.829 Mach). During climb, with the engines operating at METO power, the propellers had a blade passage frequency of 63.4 times per second and a blade tip velocity of 874.4 feet per second (0.783 Mach). During normal cruise the propellers had a blade passage frequency of 50.0 times per second and a blade tip velocity of 685.9 feet per second (0.614 Mach). Since the most intense single noise component is determined by the propellers, then the higher the rpm of a propeller blade the more intense will be the noise measured within the aircraft.

The various noise plottings in Figure 89, page 126, show results of noise measurements recorded within the passenger-cargo area during normal cruise. These measurements were recorded while the aircraft was flying at an altitude of 5,500 feet and an airspeed of 140 knots (IAS). The engines were operating at 2,000 rpm and 32 inches of manifold pressure. The frequency range exhibiting the least amount of variation at various internal locations is below 150 cps. The noise levels present in the higher frequency ranges are the product of 1) less acoustical treatment in the aft sections of the main fuselage, 2) the wider frequency range of the noise generated by the exhaust of the engines, and 3) the presence of two exit doors and a main exit-entrance ramp located in the extreme aft sections of the fuselage.

The noise levels depicted in Figure 90, page 127, and Figure 91, page 128, give a more detailed breakdown of noise exposures generated at various locations within a CV-2B during normal cruise. These plottings indicate that the general noise exposures measured at head level locations at troop seat positions next to windows one, two, and three are basically the same. In fact, the over-all noise levels differ by only three decibels between the three locations. The noise levels measured at troop seat positions at windows four, five, and six show somewhat similar noise characteristics with the exception of the noise exposures measured at the sixth window. At this position, the presence of engine exhaust noise is more pronounced and, since there is less acoustical treatment in this area, results in a somewhat more intense noise exposure.

An acoustical blanket (noise blanket) is installed in the extreme aft end of the cargo area which helps restrict noise and free airflow emanating from the openings around the aft nonoccupied areas from invading the main passenger-cargo compartment. Figure 92, page 129, shows noise measurements taken in the center line between the eighth windows. These measurements clearly indicate the significant

increase in noise levels that may exist at locations near the rear of the CV-2B when factors exist in which noise generated externally is allowed to invade a relatively nonacoustically treated area.

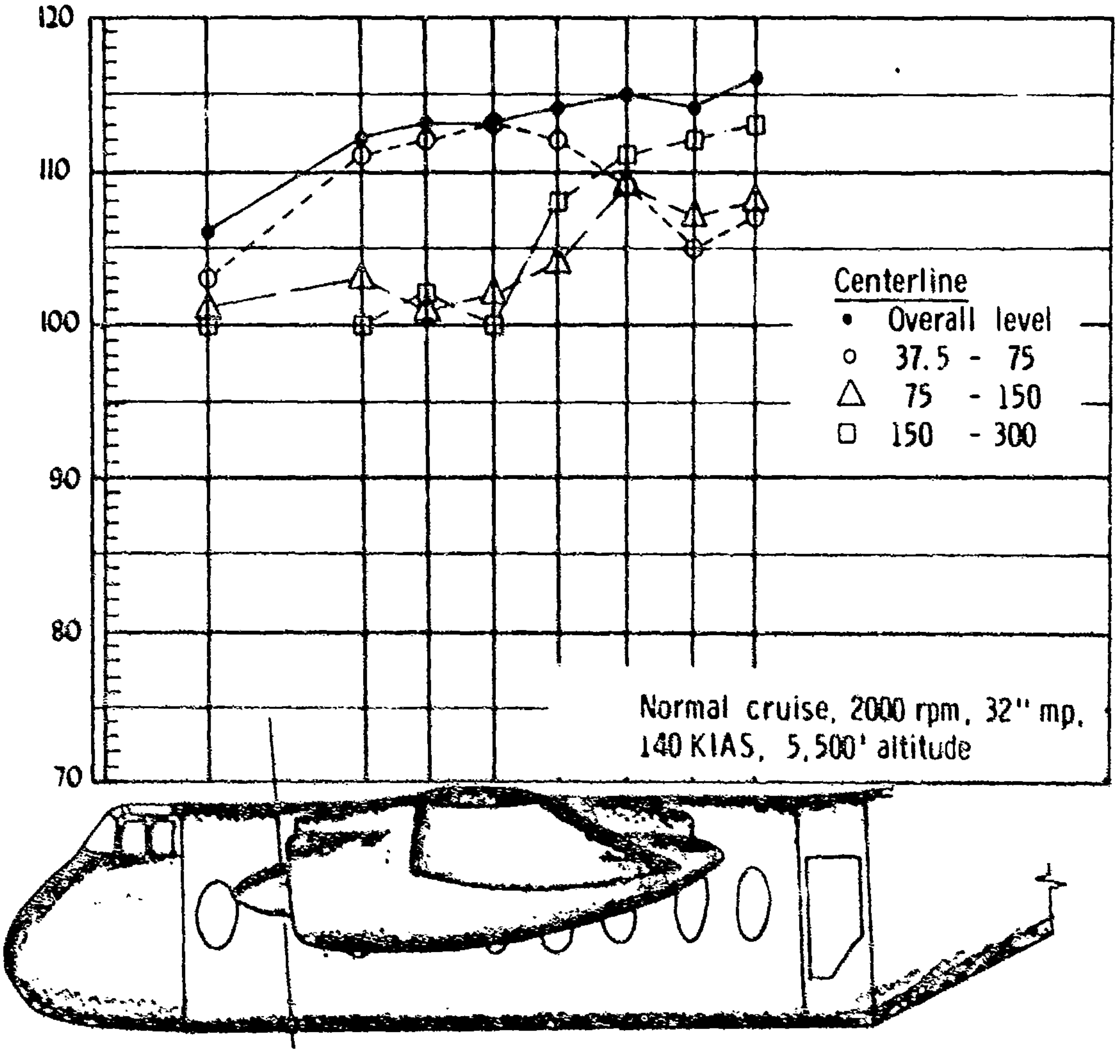

Fig. 86 Internal Noise of CV-28 Aircraft During Normal Cruise at 5500' Altitude, 2000 RPM, 32" MP, 140 Knots IAS

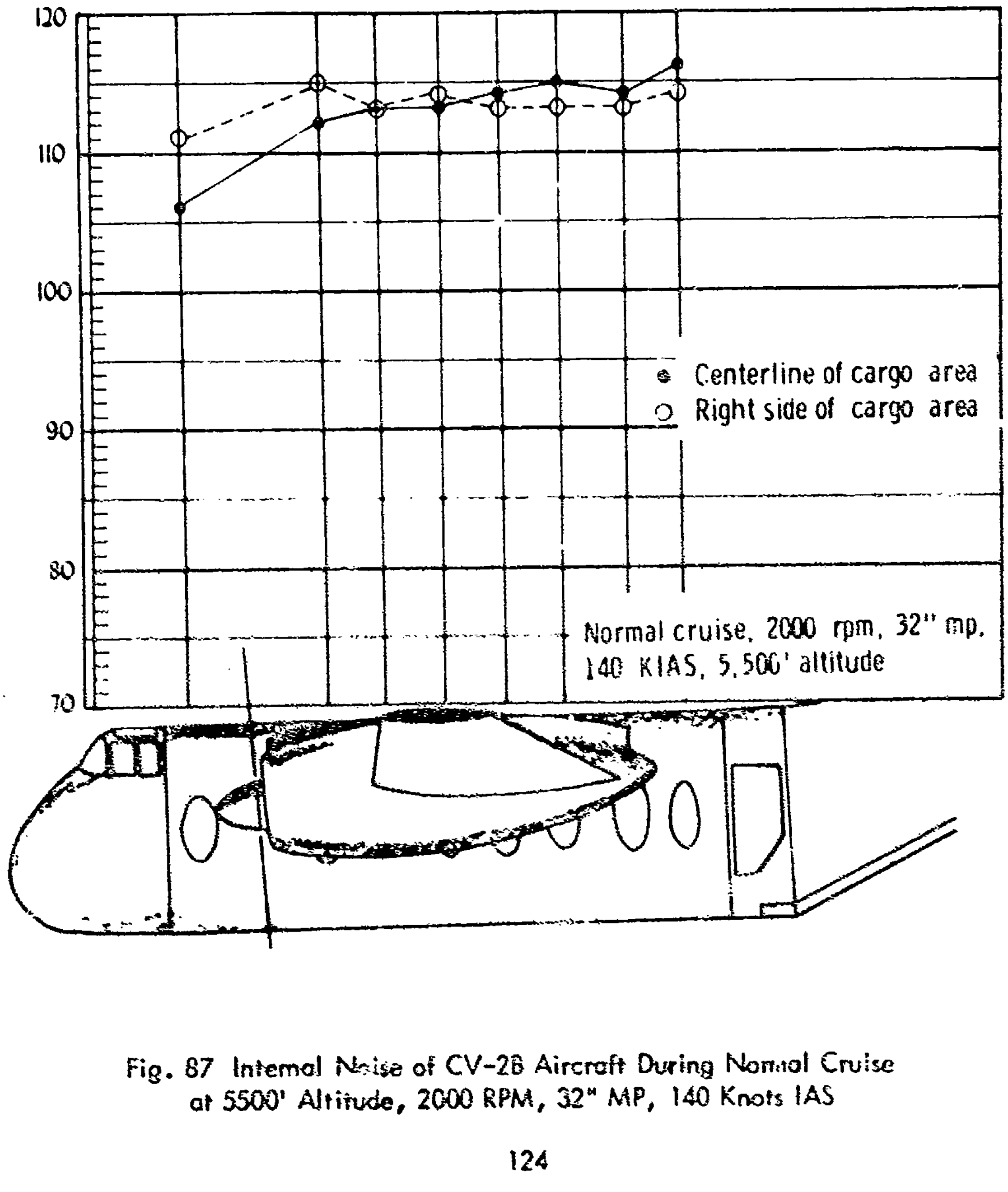

Fig. 87 Internal Noise of CV-2B Aircraft During Normal Cruise at 5500' Altitude, 2000 RPM, 32" MP, 140 Knots IAS

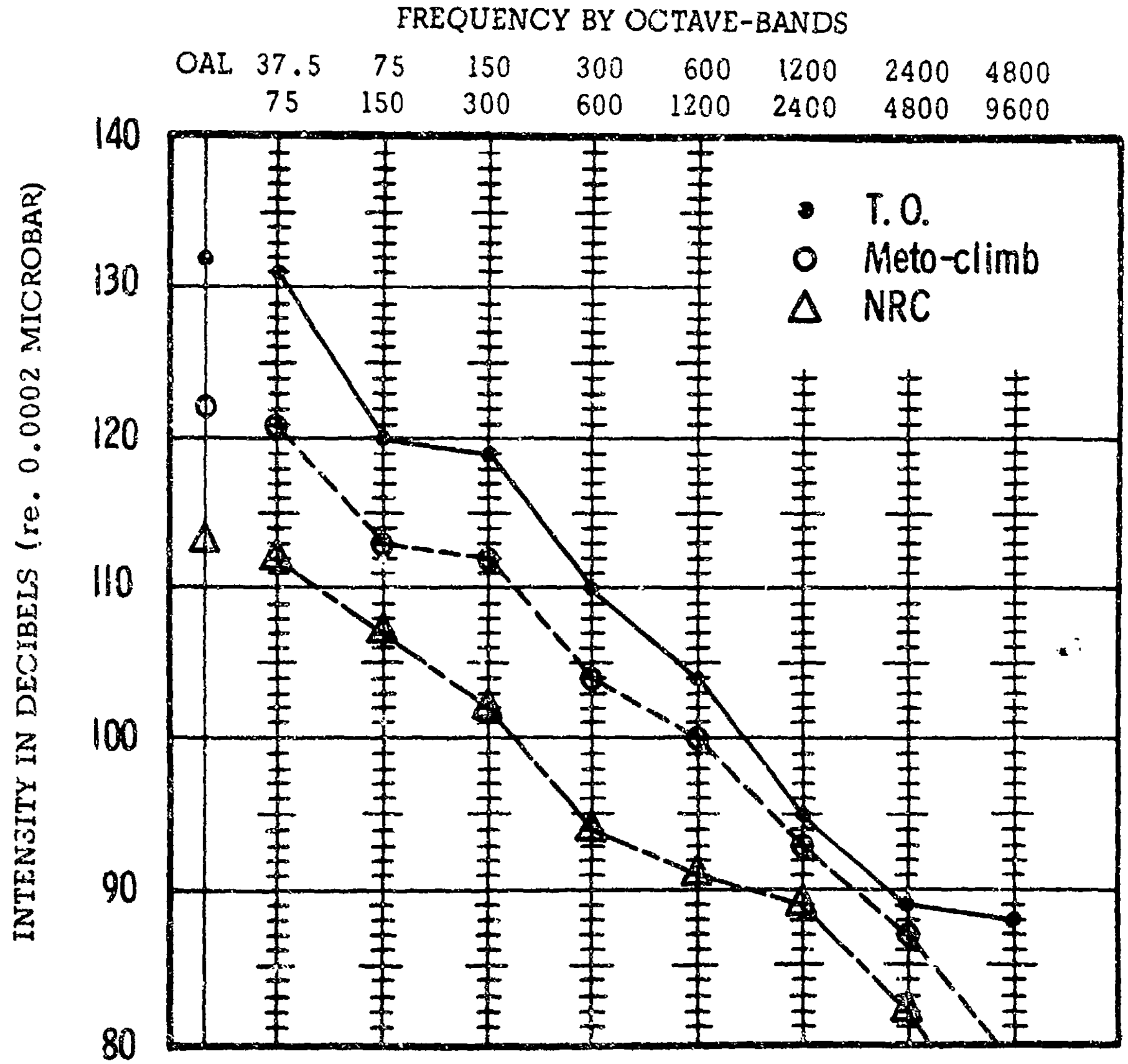

Fig. 88 Internal Noise of CV-2B Aircraft During Take-Off, Climb, and Normal Cruise

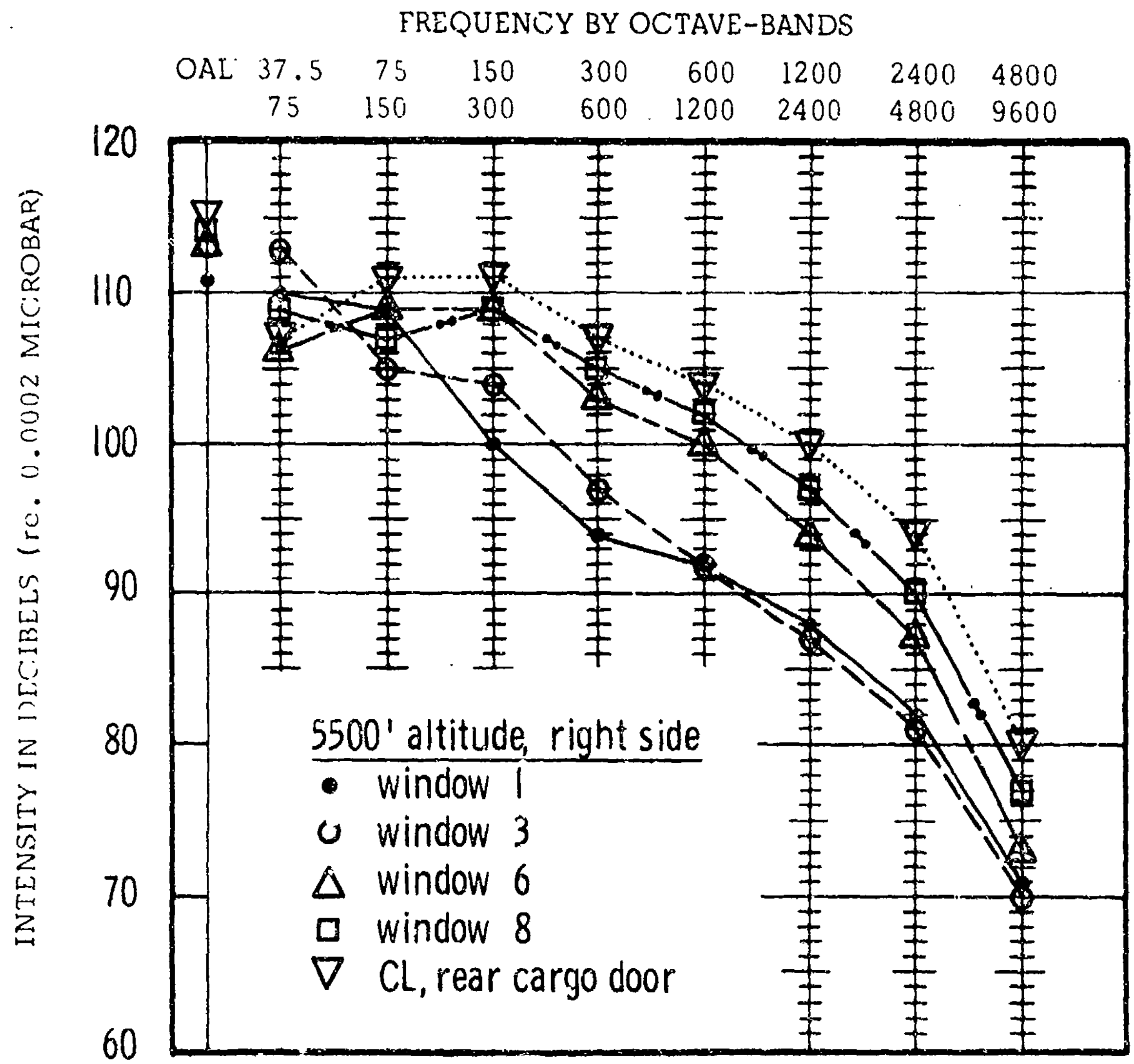

Fig. 89 Internal Noise of CV-2B Aircraft During Normal Cruise at 5500' Altitude, 2000 RPM, 32" MP, 140 Knots IAS

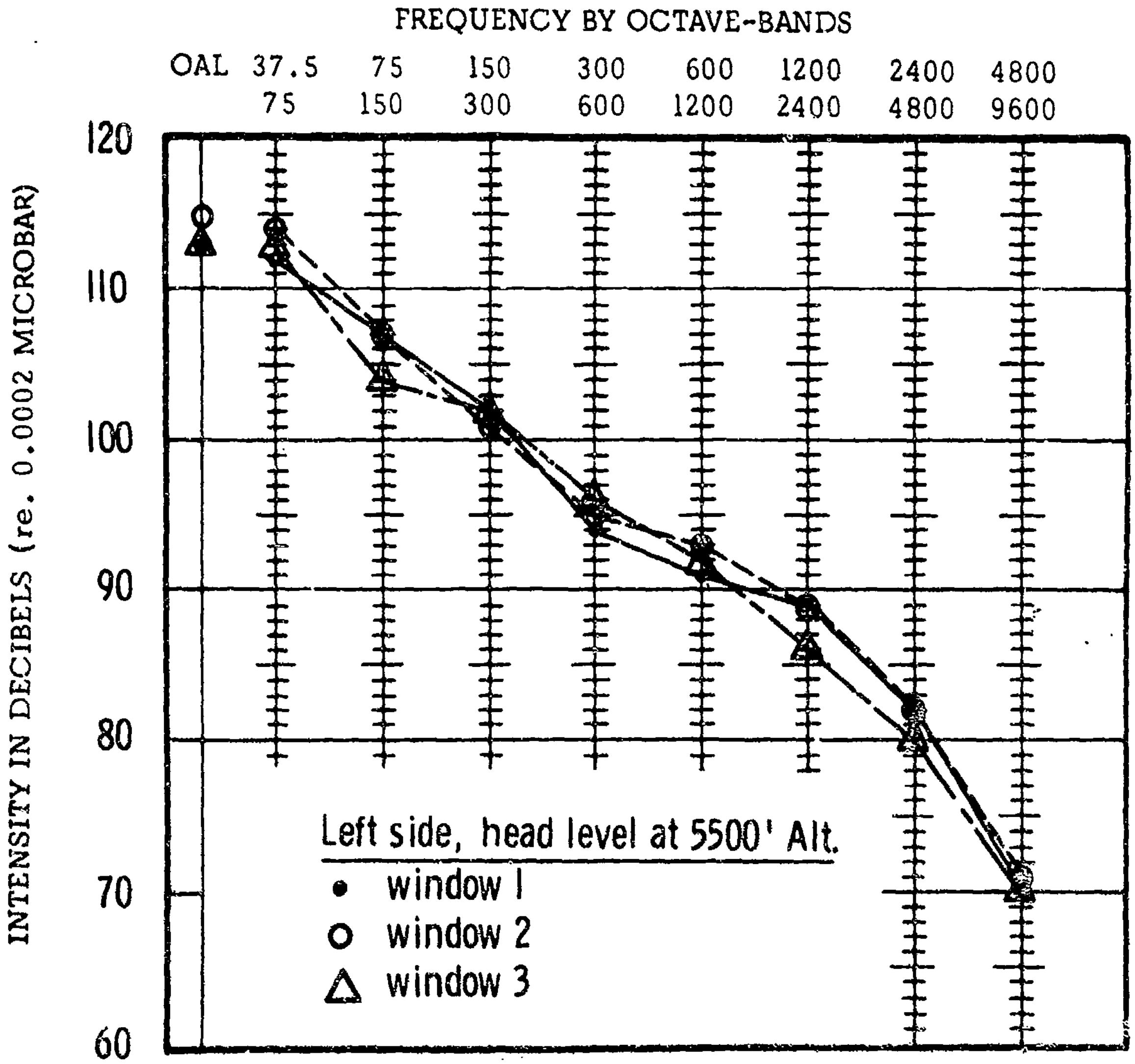

Fig. 90 Internal Noise of CV-2B Aircraft During Normal Cruise at 5500' Altitude, 2000 RPM, 32" MP, 140 Knots IAS

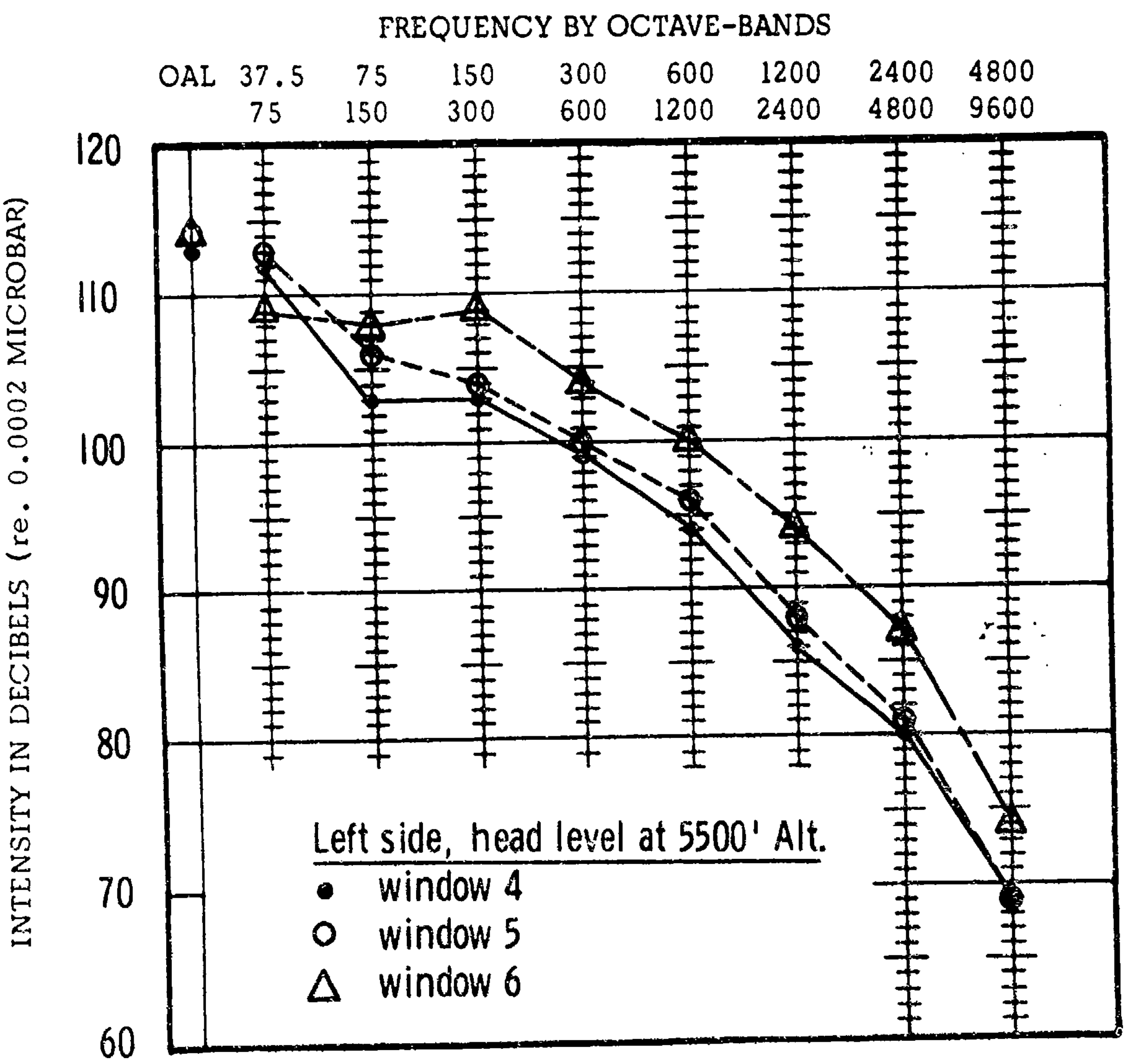

Fig. 91 Internal Noise of CV-2B Aircraft During Normal Cruise at 5500' Altitude, 2000 RPM, 32" MP, 140 Knots IAS

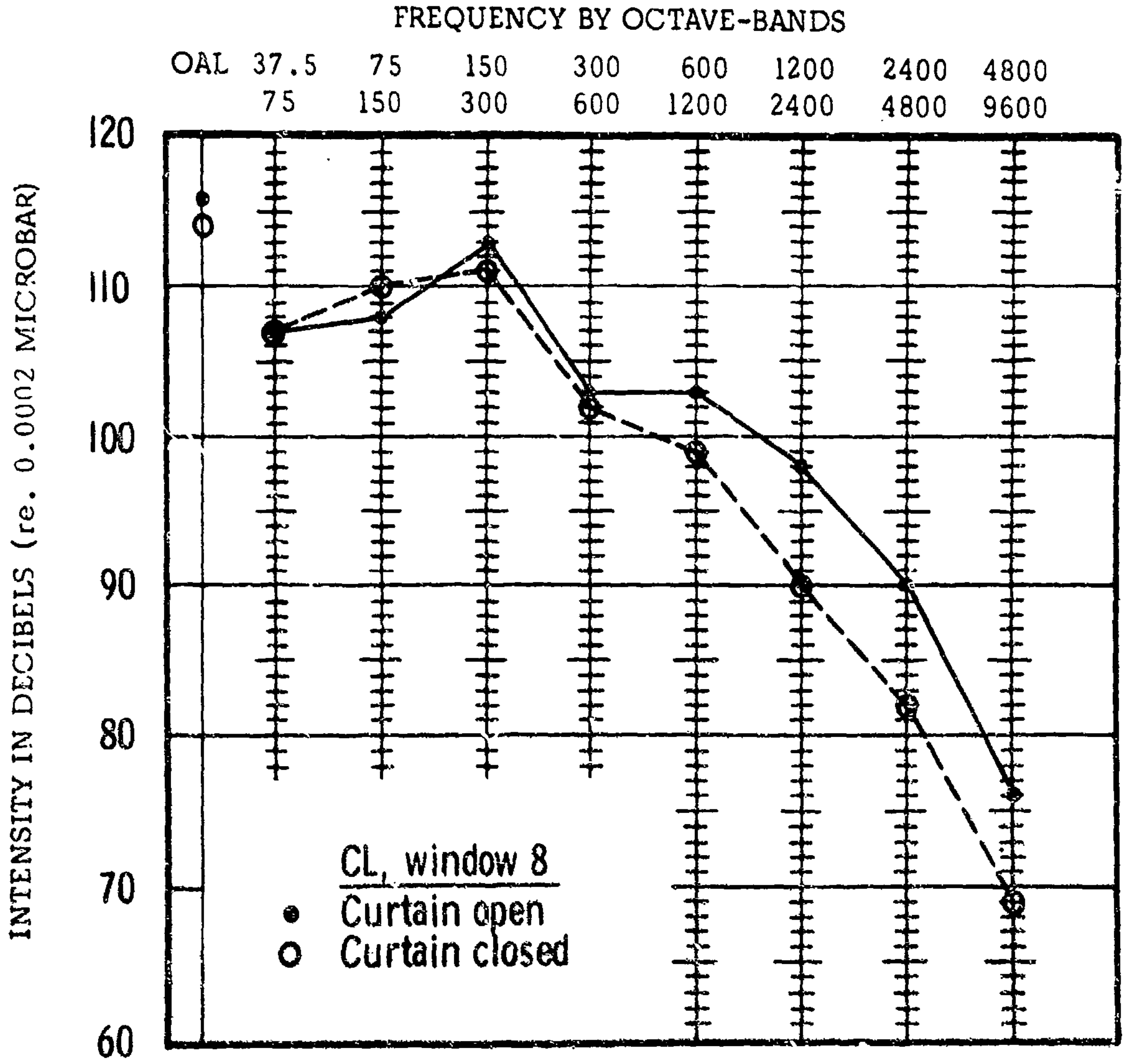

Fig. 92 Internal Noise of CV-2B Aircraft During Normal Cruise at 5500' Altitude, 2000 RPM, 32" MP, 140 Knots IAS

C. Observation Aircraft

O-1E.

The O-1E is a small single-engine, two-place monoplane powered by a single Continental 0470 in-line reciprocating type engine that produces approximately 213 brake horsepower at 2,600 rpm at maximum power and approximately 190 brake horsepower at 2,300 rpm. The aircraft is fitted with a two-blade propeller with a diameter of 7'6". The propeller of the O-1E is of all wooden or metal construction with both propeller types having a fixed pitch. Therefore, the engine rpm is the determining factor of propeller thrust and relative noise levels.

Internal Noise: Figure 93, page 132, illustrates noise levels generated at head level of the occupant in the front seat during various phases of powered flight. The most intense noise was recorded during take-off. During other phases of flight the noise is generally louder as engine power is increased, except for the levels recorded during very low cruise conditions. At low cruise the engine was operating at 1,800 rpm and the propeller had a blade passage frequency of 60.0 times per second and a blade tip velocity of 706.8 times per second (0.632 Mach). It is interesting to note the existence of natural modes of resonance which exist within the aircraft during low cruise and which cause an increase in the amount of noise produced internally. At higher power settings this phenomenon apparently does not exist. At normal cruise the engine was operating at 2,150 rpm and the propeller had a blade passage frequency of 71.7 times per second and a blade tip velocity of 844.2 feet per second (0.755 Mach). The noise measurements shown in Figure 94, page 133, were recorded at the head level of the occupant in the rear seat during taxi, take-off, and climb. The most intense noise components were present during take-off, and the general noise characteristics are basically the same as those recorded in the front of the aircraft during the same phases of flight.

Figure 95, page 134, shows the influence of increased airspeed on the noise generated at the head level of the pilot in the front seat. These measurements were completed while the aircraft was flying at a low cruise of 75 miles per hour (IAS) and at a high cruise of 107 miles per hour (IAS). An increase in airspeed causes increased aerodynamic disturbances which are produced by the passage of the slipstream over the sides of the fuselage, especially on the right side next to the entrance door. The over-all noise levels did not change during these two conditions, but the frequency spectrum did show a definite change, especially in the higher frequency range.

External Noise: The noise levels shown in Figure 96, page 135, were recorded at a distance of about twelve feet from the propeller hub during ground run-up

of the engine. The engine was operating at 1,400 rpm (idle power) and the noise measurements were recorded at various locations around the engine. Locations farther aft than 135 degrees were not possible because of air turbulence created by the propeller. At a location directly in front of the aircraft, the noise spectrum is more evenly distributed throughout the frequency range from 37.5 through 1200 cps.

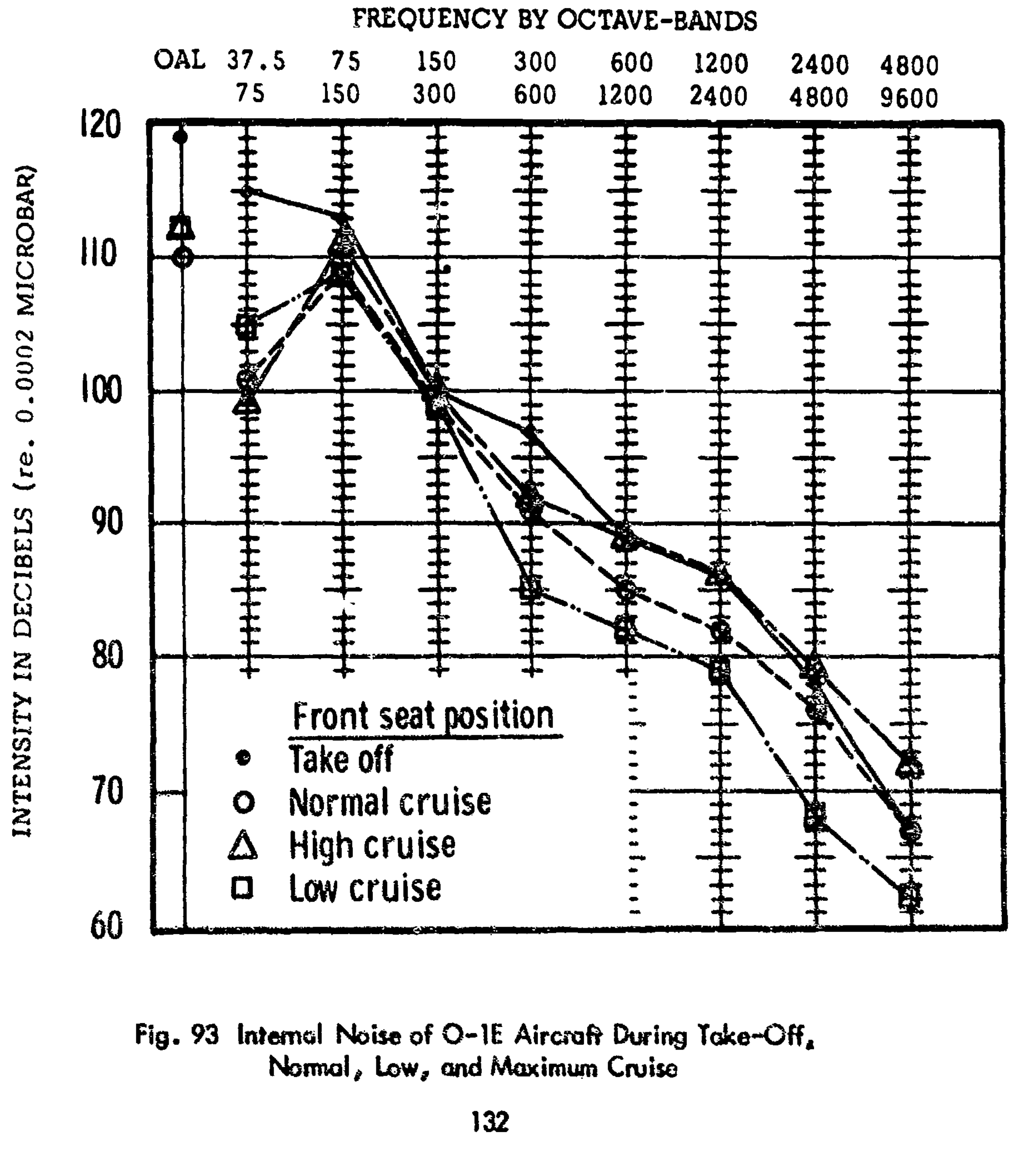

Fig. 93 Internal Noise of O-1E Aircraft During Take-Off, Normal, Low, and Maximum Cruise

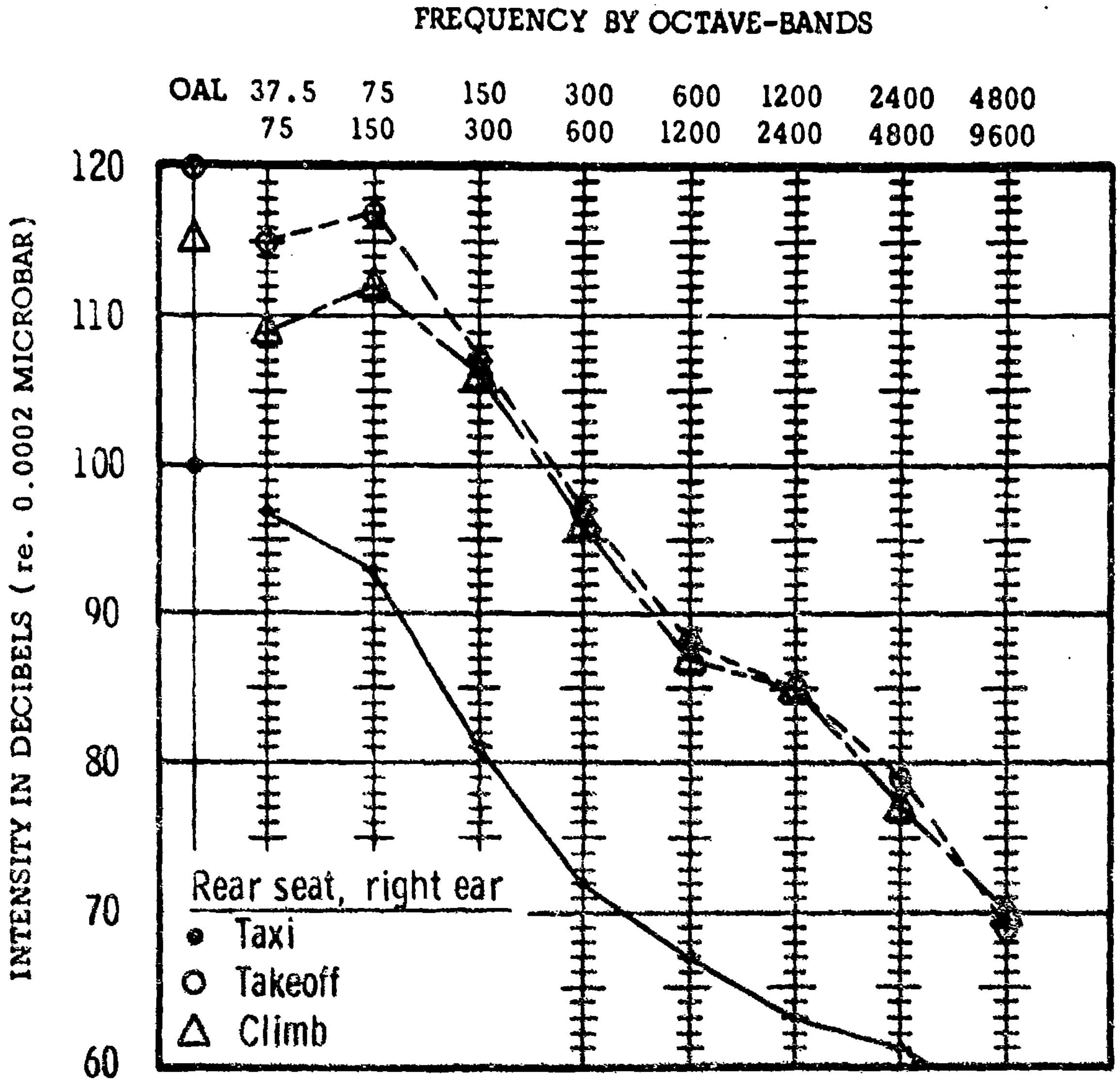

Fig. 94 Internal Noise of O-1E Aircraft During Taxi, Take-Off, and Climb

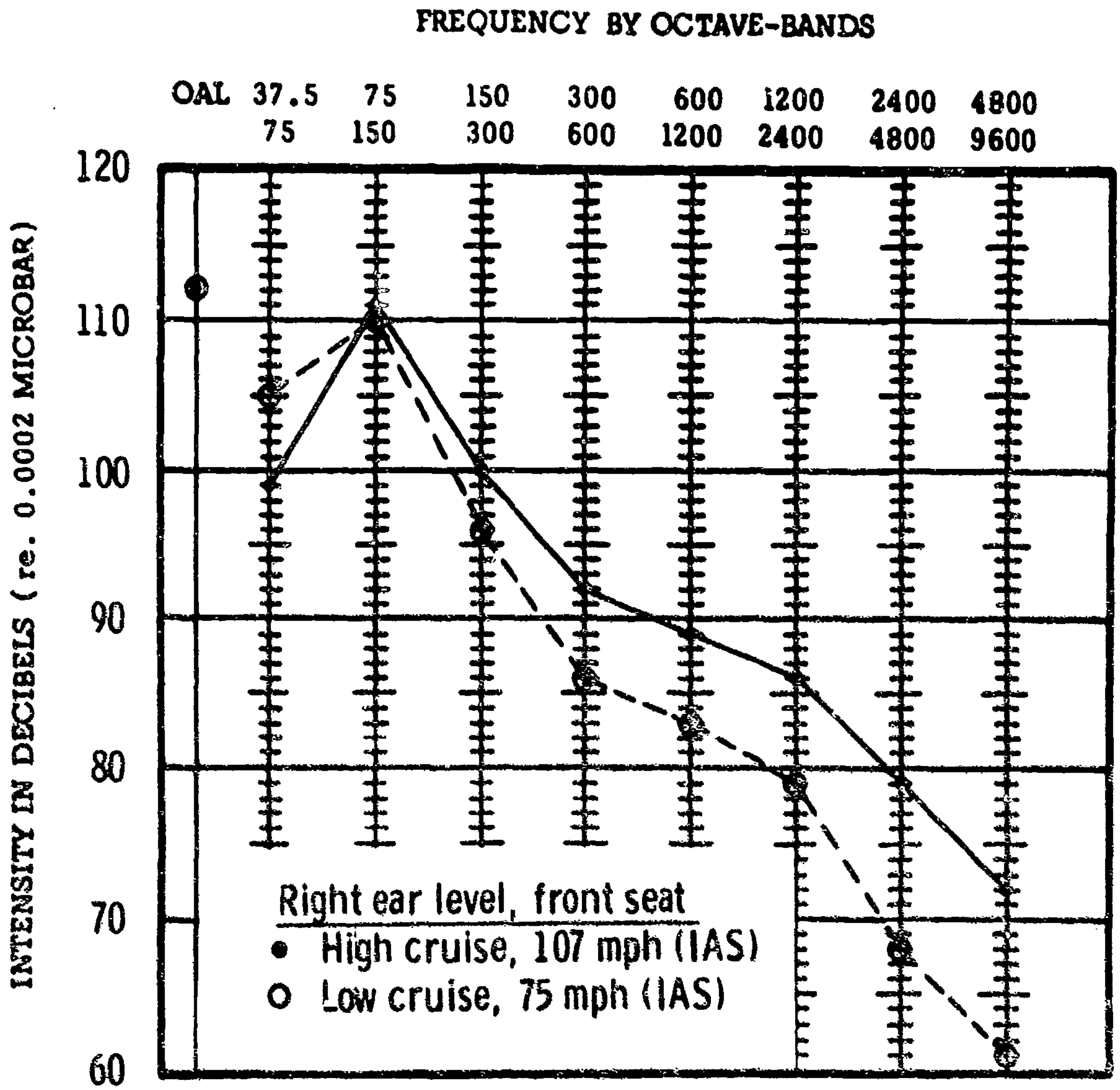

Fig. 95 Internal Noise of O-1E Aircraft, Low versus Maximum Cruise

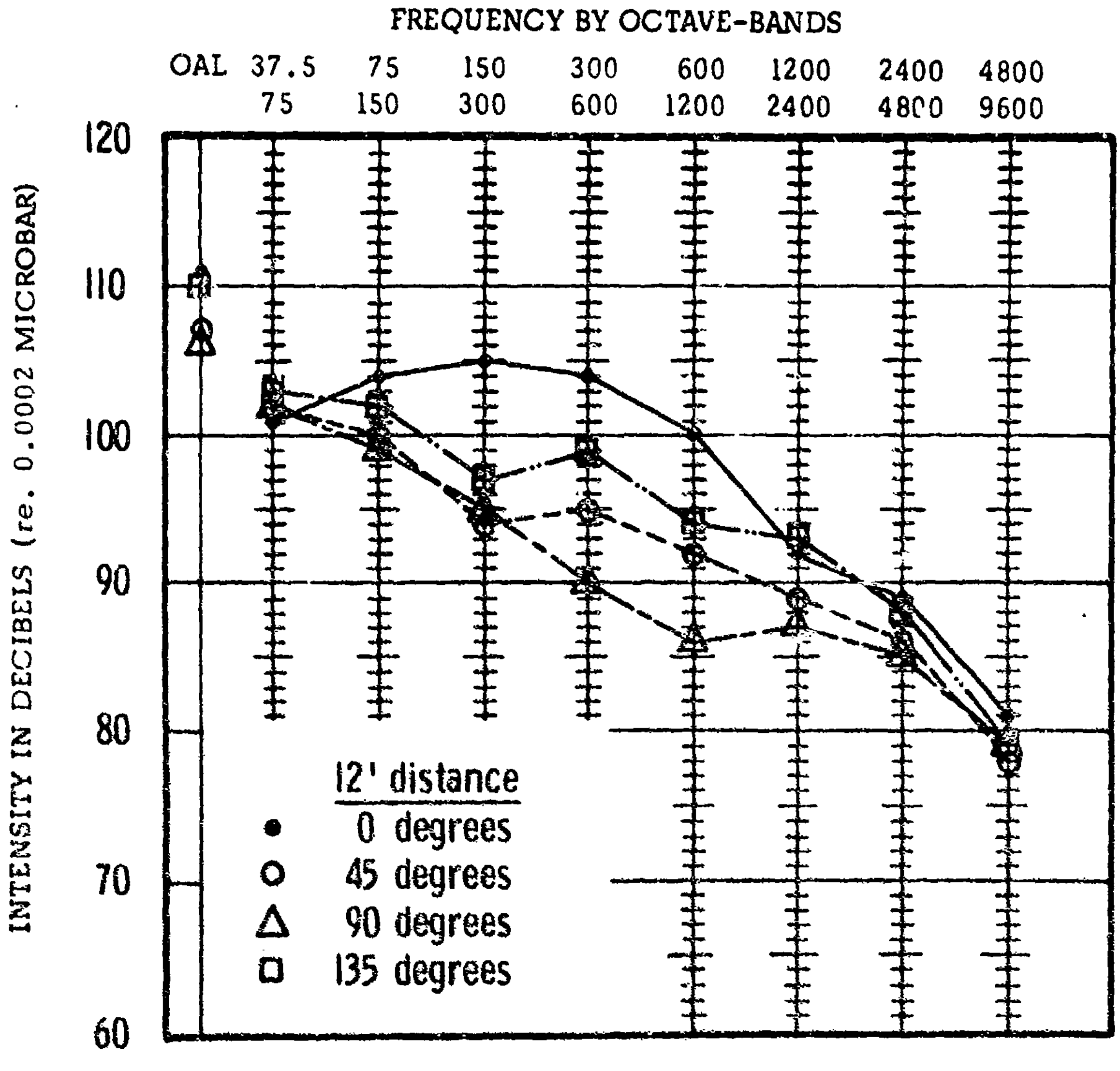

Fig. 96 External Noise of O-1E Aircraft During Ground Operations at Idle Power, 1400 RPM, Measured at 12' Distance

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